STORMPAC

Version 4.1

User Guide

STORMPAC USER GUIDE

VERSION 4.1

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1. THE STORMPAC USER GUIDE

1.1 STORMPAC

1.1.1 Overview

STORMPAC is a software package combining a Stochastic Rainfall Generator (SRG) with Disaggregation models [1] [3], and hourly rainfall processing capabilities. The range of facilities available is:

i) Generation of hourly rainfall time series for any location in the UK.

ii) Threshold analysis of generated hourly rainfall and historic daily rainfall data.

iii) Processing of hourly rainfall (historical or generated) into a chronological event database.

iv) Sorting the chronological event database using storm depth, intensity, duration, dry period, Urban Catchment Wetness Index (UCWI), 30-day Antecedent Precipitation Index (API30) or bathing season as the identifier.

v) Disaggregation of hourly rainfall data into 5-minute rainfall intensity values using a new disaggregation model.

vi) Five-minute intensity values output in a format suitable for input to HydroWorks[1], InfoWorks, Rwin or SIMPOL 2.1.

The current version of the STORMPAC Annually Regionalised SRG is not recommended for use with higher rainfall catchments where the average altitude is above 381 m or where there is a local microclimate. In these situations local historical data should be used.

1.1.2 Who will use STORMPAC?

STORMPAC has been specifically developed as part of the Urban Pollution Management (UPM) programme [2] and is intended for use in conjunction with the other software packages identified within those procedures. However, the long rainfall time series which are produced can be used for other applications.

1.1.3 User inputs

The SRG only needs a few inputs from the user to produce hourly rainfall data. Essential inputs are grid reference, distance from coast, altitude and some local rainfall statistics (calculated from actual daily rainfall data or from published tables) and are obtainable from the Meteorological Office (Met. Office).

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[1] Contact Wallingford Software for details of the Hydroworks and Infoworks products; Stormpac generates Rainfall RED files that are compatible with these applications.

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Historical hourly data, when available, are usually obtained from the Met. Office, however the data may need to be reformatted so that STORMPAC can read it.

Soil Moisture Deficit (SMD) data (monthly average or daily values) are necessary if representative UCWI values are required. API30 values are also calculated and both UCWI and API30 are output to the same HydroWorks files.

The remaining inputs to the various sections of STORMPAC are all created internally by the software. However, files created externally to STORMPAC can be read by the package if they are in the correct format.

1.1.4 What is new in STORMPAC 4.1?

- Rainfall series of up to 100 years can now be generated
- Calculated SRG parameters and upper and lower parameter limits can be viewed
- Graphical views comparing simulated results with historical data are produced
- Updates to Data Views function
- Create output file function for multi-site RED generation speeded up

1.1.5 What was new in STORMPAC 4.0?

- RED file output includes evaporation on the first profile (used in Wallingford runoff model)
- Options added to speed up Poisson disaggregator
- Chart display to compare summary statistics for imported daily rainfall and generated rainfall
- Time filter on Event definition form
- Multi-site RED generator available – this allows the user to generate RED files with many rain profiles.

1.1.6 What was new in STORMPAC 3.2?

- Imports up to 50 years of rainfall data
- Output files are exported to the directory and folder selected by the user
- Updates to the user interface
- The STORMPAC database will record:
  - Criteria used to select rainfall events

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- Parameters used in the SMD calibration and UCWI calculations
- Imported SMD data

- A new Poisson rectangular pulses dissaggregator – this is an improvement on the previous Ormsbee method disaggregator, particularly for extreme rainfall values (see Section 2.3.3 for further details).

1.2 User Guide Contents

1.2.1 Objectives

This guide is designed to tell you what STORMPAC can do, and how to install and use the software. It is aimed specifically at the first time or the occasional user. Brief details about the SRG and the Disaggregation models are given and references are provided for further reading.

1.2.2 Organisation

Sections 1 to 4 of this User Guide provide a general background to STORMPAC, including installation, instructions and a worked example.

Sections 5, 6, 7 and 8 detail the user inputs (and formats) necessary for all the functions of STORMPAC, describing all the button functions relating to each form in the software, the SMD model and listing some frequently asked questions.

Section 9 includes references for further reading on both the background to the models and the UPM programme.

The Appendices provide worked examples of using the SRG and a flow diagram suggesting a working methodology.

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2. SIMULATION AND PROCESSING OF RAINFALL TIME SERIES

Introduction

This section introduces in more detail what the STORMPAC package can do and what it can be used for. It also tells you more about how the SRG and Disaggregation models work and the data inputs that are required.

2.1 What STORMPAC can do

2.1.1 Main Purpose

STORMPAC has been developed specifically for producing suitable rainfall data for input to other models as part of the UPM programme. It achieves this by utilising the SRG, Disaggregation model and processing software which analyses, samples and reformats rainfall data.

2.1.2 Hourly rain data

STORMPAC can simulate hourly rainfall time series for a site, using the SRG, or process historical hourly rainfall data.

2.1.3 Series length

When importing a historical data series into Strompac the maximum length is 50 years. However, when generating a rainfall series without any historical data, the maximum series length which can be created is 100 years.

2.1.4 Storm Identification

After processing the hourly synthetic or historical rainfall time series STORMPAC can produce a chronological event database. Each event is identified and the event depth, duration, maximum and mean intensities, and antecedent dry period are calculated. UCWI values and API30 values are also written to this database. An event is usually defined as having at least a one hour inter event dry period. However, STORMPAC will allow the user to specify a minimum inter event dry period of between one hour and the rainfall series length in hours. The event database can also be saved to a Comma Separated Values (CSV) file for use with programs such as Microsoft (MS) Excel.

2.1.5 Sorting

The chronological event database can be sorted by STORMPAC (in descending or ascending order) on seven criteria:

- Time (event number)

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- Total event depth
- Mean rainfall intensity
- Maximum hourly rainfall intensity
- Duration
- Dry period
- UCWI
- API30

In addition, the output can be edited to select only events occurring during the months in the bathing season (May to September) or for a shorter time period. Typically, the first four criteria will be used to sort the data.

2.1.6 Selection

Once the events have been sorted the first x storms can be selected, where x is a number between one and the maximum number of storms identified and sorted.

2.1.7 Disaggregation

The entire historical or SRG hourly data series can be disaggregated down to a five-minute intensity value.

2.1.8 InfoWorks/HydroWorks/Rwin/SIMPOL

STORMPAC formats the data following disaggregation into files compatible with InfoWorks, HydroWorks, Rwin and SIMPOL hydraulic models.

2.2 When and how the SRG can be used

2.2.1 SRG Testing

Testing of the output from the SRG model in STORMPAC 2.0 as a substitute for historical rainfall data in sewer models has been undertaken and reported in an FWR report[3]. Recommendations from the report are shown below. They are intended to increase the level of confidence that the user can have when using rainfall series.

2.2.2 Report Recommendations

1. Long complete hourly rainfall historical data series, if available, will provide maximum accuracy for any modelling study. The necessary length of this series will depend on the user requirements. For pollution management studies at least ten years should be used.

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If specific extreme events are required, for example up to a ten-year return period, a series in excess of 20 years is necessary.

2. Accuracy in the SRG model can be improved if daily rainfall data are used to help regionalise the model. Availability of these data is relatively widespread and can be obtained from the Met. Office. At least 20 years of daily rainfall data should be obtained to ensure the data are representative of the site.

3. The longer the series generated by the SRG, the less likely extreme years will bias the results. To some extent this is the same for historical data. Twenty years are recommended, but not less than ten should be considered for most applications.

STORMPAC 3.0 (and hence versions 4.0 and 4.1) is an improvement on the previous STORMPAC 2.0 in that extremes in data, as seen in historical rainfall data series, are modelled with greater accuracy. The recommendations given for STORMPAC 2.0, therefore, hold for all later versions of STORMPAC.

2.3 How the SRG and Disaggregation models work

2.3.1 Background

The detailed background of the SRG and Disaggregation models incorporated in STORMPAC are not covered in this User Guide. Users requiring this information should refer to FWR report FR0217[3] Threlfall *et al*. 1998[7], Cowpertwait 1998[8] and Cowpertwait 2000 [21]. A summary of the two models is given below.

2.3.2 The SRG Model

Regionalisation

Parameters have to be regionalised within the model to make the synthetic hourly rainfall series representative of local conditions. To achieve this, the model requires some local site characteristics and rainfall statistics. Further details on the necessary user inputs are given in Sections 2.4 and 5. Two versions of the SRG exist in STORMPAC 4.1: an **Annually Regionalised** version and a **Daily Regionalised** version. It is also possible to produce **weighted averages** of site statistics if short (less than 10 years) daily or hourly historical rainfall records are available at a site.

The SRG model generates storm events, where the storm event contains a series of (possibly overlapping) rain cells. The storms arrive as a Poisson process, with rate parameter Lambda (per hour). Each storm generates a number of rain cells, taken from a Poisson distribution with the mean number of cells per event being given by the parameter 1/Nu. The average time between rain events within the storm is given as an exponential distribution with parameter Beta (per hour). Each rain event is exponentially distributed with parameter Eta (per hour). Finally, the intensity of the rainfall is taken as an exponential distribution, with parameter Shape (hours per mm).

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Annually Regionalised

The Annually Regionalised version of the SRG utilises average annual rainfall data to help in the regionalisation process. This version has not been developed for use for catchments with a microclimate or with an average altitude above 381m and corresponding high SAAR values. User experience suggests the Annually Regionalised SRG should not be used where the SAAR is above 1500mm. The use of historic data is recommended in these situations.

99 rainfall sites were used in calibration of the annually regionalised model, these are shown in Figure 2-1.

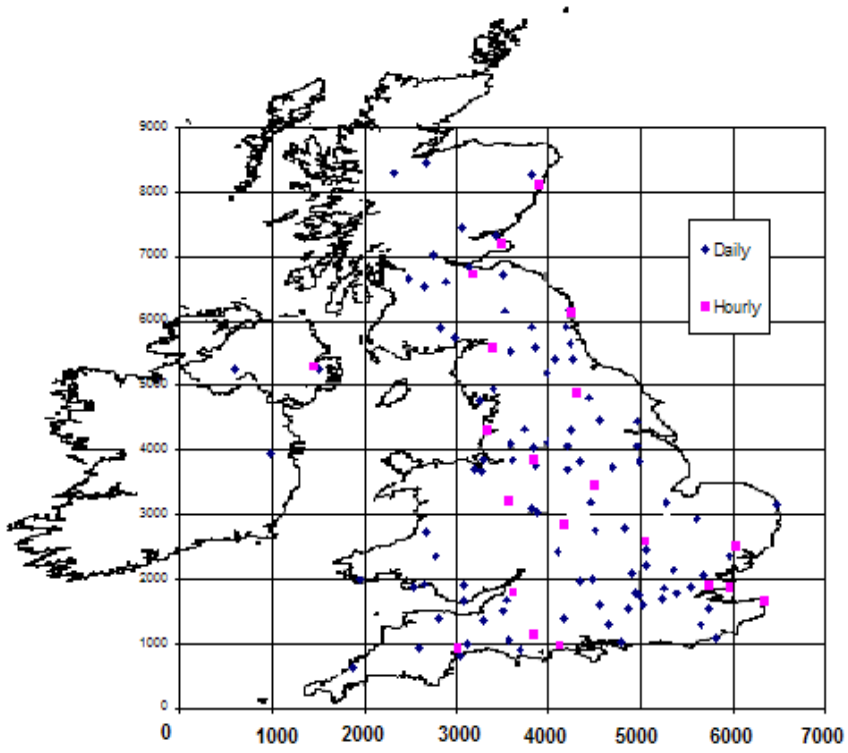

Figure 2-1 Sites used in calibration of the regionalised model

Daily Regionalised

The Daily Regionalised version utilises historical daily rainfall data in its regionalisation process and is recommended if 20 or more years of local historical daily rainfall data are available. This is particularly relevant if a microclimate is expected at the study site.

STORMPAC 4.0 uses the Nelder-mead method of optimisation. This method is often called the Simplex method, and does not require derivatives of the optimisation function. This has the advantage of making it robust, as it will not be affected by any discontinuities in the optimisation function, but it is slower than methods that use gradient information. For more information see Nelder and Mead (1965)[18], McKinnon (1999)[19] and Mordecai (2003)[20] .

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STORMPAC 4.1 gives the option to view parameters relating to the SRG model. The upper and lower bounds of parameters Beta, Eta, Nu, Lambda and Shape (detailed above) have been added to the simulate SRG data screen.

Once parameters have been calculated against the default upper and lower bounds they will be shown in a table at the bottom of the screen (see Figure 2-2). When rainfall has been simulated check the fit using the graphical views and compare functions. If fit is poor note the values of the calculated parameters compared with the upper and lower bounds for the five parameters. In Figure 2-2 Beta is mostly at the lower bound, and Nu and Lambda are mostly at the upper bound.

	Beta	Eta	Nu	Lambda	Shape
Upper bound	0.5000	5.000	30.00	0.0400	5.000
Lower bound	0.0410	0.510	1.00	0.0010	0.050

	Beta	Eta	Nu	Lambda	Shape
Jan	0.041	2.56	20.7	0.0398	0.153
Feb	0.041	3.13	30	0.04	0.0801
Mar	0.041	2.97	30	0.04	0.0783
Apr	0.041	2.14	30	0.04	0.0708
May	0.041	2.83	20.8	0.04	0.05
Jun	0.152	2.65	26.2	0.0232	0.0504
Jul	0.329	3.48	26.4	0.0186	0.05
Aug	0.195	2.92	14.2	0.0393	0.0503
Sep	0.041	2.59	30	0.04	0.05
Oct	0.041	2.23	30	0.035	0.0692
Nov	0.041	2.44	25.8	0.0391	0.113
12	0.041	2.37	28.7	0.04	0.0905

Figure 2-2 Calculated SRG parameters

Weighted Estimates

At some sites there may be some limited historical data available in which case it would be appropriate to use weighted averages of the regression estimates and site estimates taken from the site data. A check box is available to switch this function on or off. Statistics are calculated using the available historical data and regionalised model. It is typical to use this function if only a limited amount of hourly data is available at a site.

Generation

The rainfall time series is produced using random numbers with the regionalised model algorithms. Although STORMPAC can produce 100 years of simulated rainfall, it is recommended that series that are the same length as historical rainfall series are produced (the maximum length for a historical series is 50 years). The generated rainfall statistics cannot be checked against historical data if longer series are generated. In the absence of historical data, it is recommended not to produce series with lengths greater than 30 years. This approach should be suitable for the majority of applications.

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2.3.3 The Disaggregation Model

General

The disaggregation model within STORMPAC 3.2 has been upgraded from the Ormsbee method, Ormsbee (1989)[12], used in previous versions of the software. A Poisson rectangular pulses model was first employed within STORMPAC 3.2. This model was first studied in detail by Rodriguez-Iturbe et al (1987)[13] and subsequently extended by Cowpertwait et al (2004)[14] to disaggregate spatial hourly data.

The methodology adopted is similar to that used by Glasby et al. (1995)[15] in that 'within storm' rain cells have arrival times that occur in a Poisson process. However, these authors used a Bartlett-Lewis process to disaggregate daily data to hourly data, whilst the approach used here is a simple Poisson process to simulate fine resolution series directly.

In the Poisson rectangular pulses model, rain cells have arrival times that occur in a Poisson process. Each rain cell has a random lifetime, which is distributed as an independent exponential random variable. The intensity of each rain cell remains constant throughout the cell lifetime and has been taken to be an independent Weibull random variable. The total rain intensity at any point in time is the sum of the intensities of all cells alive at that point. The model has been fitted using a minimisation procedure, which matches model properties to their equivalent within the sample data, and is based on a squared differences methodology, as devised by Cowpertwait et al (1991, 2004)[1] [14].

Model Validity

Using the fitted model and these model properties, estimates of the variables above were made for each calendar month from over thirty years of UK five 5-minute data. Following Cowpertwait et al (2004) [14], only wet hourly sequences are included in the estimation of these sample properties. Fifty years of 5-minute data were simulated for each month using the fitted model. The historical and simulated distributions of 5-minute rainfall were compared on quantile plots for each month separately and showed good correlation, Cowpertwait (2005)[16].

Cowpertwait et al (2004)[15] had found that the spatial Poisson rectangular pulses model performed well when disaggregating hourly data for input in urban catchment models justifying its use in STORMPAC for temporal disaggregation, as this is just a special case of the spatial Poisson rectangular pulses model. The good correlation reached between historic and simulated 5-minute data, Cowpertwait (2005)[16], adds credence to the use of the fitted model in the disaggregation procedure.

Overall the fitted Poisson rectangular pulses disaggregator also showed a notable improvement upon the Ormsbee method, especially in regard to the extreme values where the Ormsbee method tended to underestimate. Therefore, it is recommended as a suitable replacement to the Ormsbee disaggregator, Cowpertwait (2005)[16]. Appendix C presents a comparison of the new Poisson and old Ormsbee methodologies, evaluating them both against historic data using quantile plots. This highlights the improvement seen using the new Poisson method. It should be noted that although the option is still available to use the Ormsbee method it should only be used to replicate rainfall sets created in previous STORMPAC versions (up to and including 3.1).

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Disaggregation Procedure

The disaggregation procedure can be summarised as follows. A 1-hour rainfall depth is read in from the database, which contains the hourly series to be disaggregated. A 5-minute series is simulated using the fitted model. The 5-minute simulated series is summed and the 1-hour total of the simulated series compared to the 1-hour total that was read in. The simulated series is discarded if the absolute difference between the simulated 1-hour total and the total read in exceeds 5%. The process is repeated until the totals are in agreement to within 5%. The simulated series then represents a possible realisation of 5-minute data representative of the 1-hour value that was read in. Following this procedure, a record of 1-hour rainfall depths can be disaggregated.

Some additional rules are applied: These include using overlapping 5-minute values from the previous disaggregated hour provided the total of these overlapping values do not exceed the 1-hour total to be disaggregated. This allows for some influence, due to overlapping cells, from the previous hour. In addition, the disaggregated series are scaled to achieve an exact match to the hourly series (although clearly this is only a very minor adjustment, given they fall to within 5% of the hourly total).

The disaggregator has had a new option added, *Accelerated Poisson.*

This option is only recommended if the standard Poisson method is found to be unacceptably slow. The standard Poisson method breaks the hourly rainfall into 5-minute intervals by using the following approach:

do for each hour

calculate 12 rainfall estimates from a Poisson distribution

repeat until the sum of the 12 is within 5% of the measured/SRG value

Where the hourly rainfall is large it can take a long time to choose 12 random numbers that happen to be within 5% of that value. Usually the Poisson method, for 'typical' UK rainfall, will take a few minutes to disaggregate the rainfall. WRc has had the Poisson method reported as being slow for areas of high rainfall such as the Lake District and areas of North Wales. The Poisson method successfully disaggregated the rainfall, but took in excess of eight hours to do so.

The *Accelerated Poisson* method has been added to Stormpac to cater for this. Note that the default values can be adjusted. The values were selected by comparing a series of accelerated disaggregations of a 25 year dataset to the Poisson disaggregator results. These disaggregations each took less than an hour to run (rather than running overnight).

The procedure for the accelerated Poisson method is:

1. Use the standard Poisson method up to a first iteration limit. The default is 30,000.

2. If that limit is reached without the Poisson method succeeding, relax the rainfall tolerance from 5% to a higher level.

3. Repeat the Poisson method with the relaxed tolerance up to a second iteration limit. The default is 5,000,000.

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4. At that point there are then two options.

   - The default is to stop and normalise the rainfall estimate – each 5-minute rainfall estimate is multiplied by the ratio of the required hourly value to the summed 5-minute values.

   - An alternative is to continue with the Poisson method, but to accept the first value where the sum of the 5-minute estimates exceeds the hourly value. The difference between the two is carried over to the next hour, as this difference will be negative and will reduce the required total for that following hour.

Tests showed that some runs with carry over crashed and the one run that completed had very similar results to the run with normalisation. Suggested ranges to adjust the limits are:

- first iteration limit from 10,000 to 100,000

- second iteration limit from 100,000 to 10,000,000

2.4 Data Requirements

2.4.1 The SRG

Introduction

The data inputs necessary for the SRG are required for the regionalisation of the model and are relatively easy to obtain. Full details of the input information, and the required formats, are given in Section 5 and worked examples of how to run the SRG are in Appendix A.

Input

Essential information for the SRG includes the following:

- Grid reference – 4 figure (Easting, Northing)

- Altitude (m)

- Distance from the nearest coast (m)

- Standard Average Annual Rainfall (SAAR) or local daily rainfall series (mm/year)

SAAR

The SAAR value can be obtained from the Wallingford Procedure[4], the Flood Estimation Handbook[17] or the Flood Studies Report[10]. Alternatively, you can request the information directly from the Met. Office. The advantage of using an average annual rainfall value is that the information is readily available. However, the disadvantages are that this is an approximation and may not take into account microclimatic variations. Also, it should be noted that catchments with an average altitude above 381m will typically have a high SAAR value

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and are outside of the current range of the Annually Regionalised SRG in STORMPAC (See Section 5.2, page 36). Local historical daily rainfall data should be used in these situations.

Daily Rainfall

If daily rainfall data are to be used, at least 20 years of data for an adjacent location should be obtained. The model calculates relevant statistics from these data for use in its regionalisation process. The availability of these data is relatively widespread and the Met. Office will be able to inform you of the most suitable sites and the data that are available. More details, including the required format, are given in Section 5.2.3. STORMPAC 3.2, 4.0 and 4.1 can import up to 50 years of data.

SMD/UCWI/API30

If a calculated UCWI value is required for each event in the output then monthly or daily SMD data can be used. STORMPAC calculates SMD in the way described in the Wallingford Procedure, Chapter 7.9[4]. An average monthly SMD value is needed (12 values in all) for SRG rainfall. The average is obtainable from the Met. Office (see Section 5.3). The actual monthly or daily SMD values should be obtained for the corresponding years and months of the record (that is, one value for each month or day of the rainfall record), if historical hourly rainfall data are being processed.

If a synthetic rainfall series is used it is important that the UCWI values relate to the pattern of rainfall within this synthetic series. Representative synthetic UCWI data can then be calculated. However, the UCWI data should also be physically realistic and representative of the study catchment. SMD data can be calculated using a suitable SMD model that can be calibrated against the 12 long-term average historical SMD values.

As well as calculating UCWI values, STORMPAC also calculates the API30 values required for the new UK Runoff Equation[10]. The initial thirty rainfall values are taken directly from the imported rainfall data. The method used is to take 30 days of rainfall data from the month preceding the start month of your hourly rainfall series + one year. For example, the program would select 30 days of rainfall data from December 2000, if your hourly rainfall series started on 1/1/00.

The program gives the user the option to use evaporation estimates calculated during the SMD calibration procedure, or default evaporation parameters of 1 mm/day for Winter and 3 mm/day for Summer.

Daily/Annual/SMD

The choice of site to provide the daily rainfall or average annual rainfall and the SMD source records should be as local as possible to the site under study. It is not possible to provide a general distance that can be considered ‘local’, because of the variations in rainfall, which can occur due to, for example, relief. Variations may even occur depending on the season. Each individual catchment has to be considered on its own. To decide, look at other available data for the area or consult the Met. Office. A ‘best fit’ selection may have to be made and should err on the conservative (wetter) side.

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2.4.2 The Disaggregation Model

The Disaggregation model requires historical hourly or SRG hourly rainfall data to be imported into a STORMPAC 4.1 database. Data do not have to be produced by STORMPAC to be used in the Disaggregation model.

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3. INSTALLATION OF STORMPAC ON YOUR PC

Introduction

This section will help you install and run STORMPAC on your PC.

Previous versions of STORMPAC required a security dongle to run. The current version runs a security check using CopyMinder over the internet. You can launch STORMPAC for a limited number of times if not connected to the Internet.

3.1 Hardware Requirements

To run STORMPAC, you will need a PC with the MS Windows operating system. It is recommended to be run with an 800 by 600 screen resolution or higher. During processing, temporary files are sometimes created and deleted. It is therefore advisable to have at least 20 MB of free disk space available at all times when running the software.

3.2 Software Requirements

To run STORMPAC you will need:

- STORMPAC distribution CD;
- MS Windows 95, 98, NT, 2000, XP or Vista;
- A text editor to create input files and view output files;
- Optional: MS Excel and Access 97 to view files and databases. (For information on using later versions of Access 97, see Section 8 'Frequently asked questions').

3.3 Installing STORMPAC on a PC

The installation of STORMPAC is easy using the setup routine supplied with the distribution CD. Follow the steps listed below:

- Start Windows.
- Put STORMPAC distribution CD into CD drive.
- **Browse** to select your CD Drive and select **setup**, then choose **Open.** Clicking **OK** opens the STORMPAC installation.
- Follow the simple instructions to complete the setup.

Note: The default drive and directory is C:\Program Files\WRc\STORMPAC. You must change this if you do not want the install files to be put in this default directory.

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- At the end of the Installation you will be prompted to **Restart** your computer. You should do this if you wish to use STORMPAC immediately.

3.4 Running STORMPAC

Once the software has been installed, run STORMPAC by selecting **Start**, then **Programs**, **STORMPAC** and **STORMPAC 4.1**.

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4. A SIMPLE WORKED EXAMPLE USING STORMPAC

Introduction

Once you have installed STORMPAC onto your machine you will want to see how it works. This section takes you through a relatively straightforward example and in so doing will also introduce you to many of the features in the package. Further examples are given in Appendix A.

4.1 The task

To process one year of hourly historical rainfall data and obtain the largest ten rainfall events (by depth) in the bathing season in a format suitable for input to HydroWorks.

4.2 Methodology

The main steps to be taken are shown and summarised below:

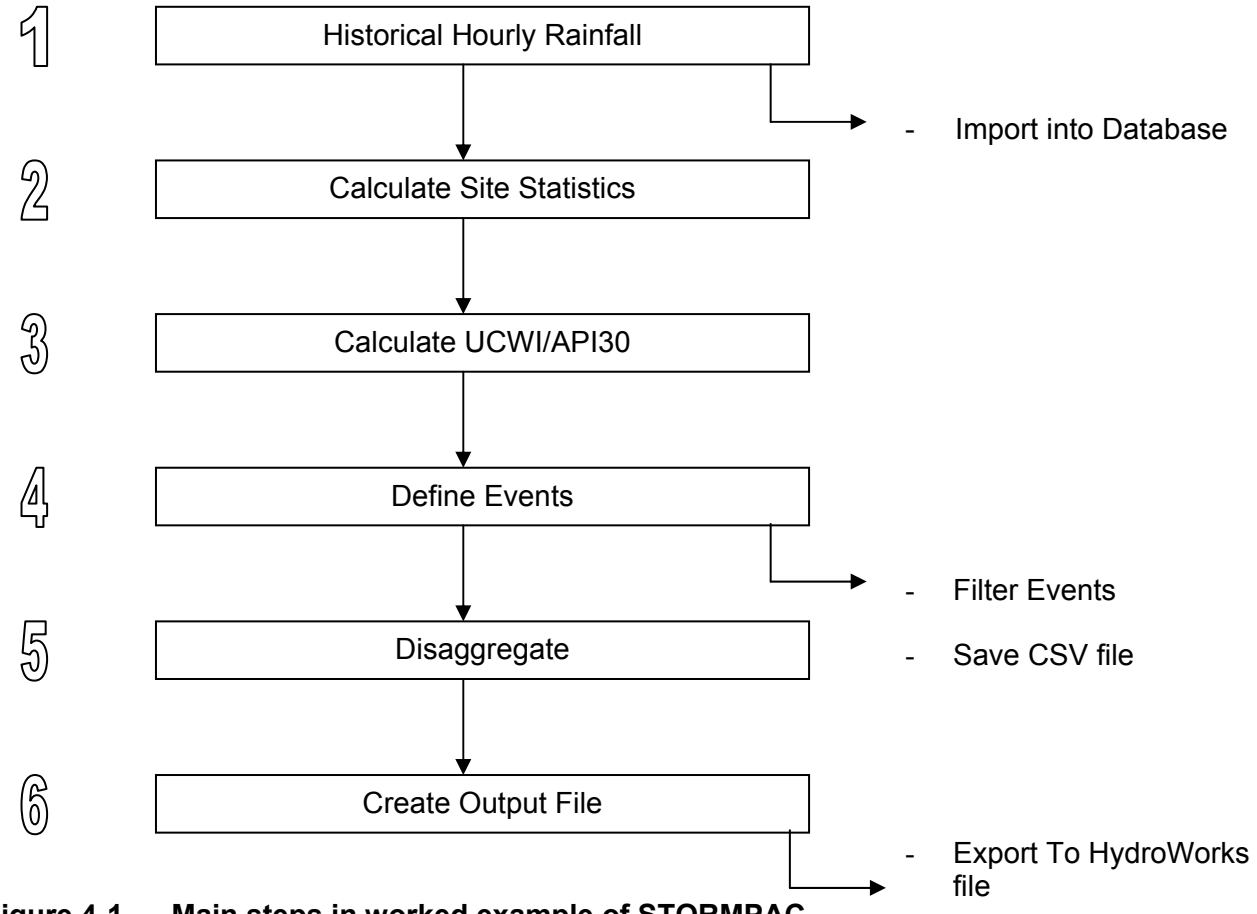

Figure 4-1 Main steps in worked example of STORMPAC

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4.3 Starting STORMPAC

Select **Start**, then **Programs**, **STORMPAC** and **STORMPAC 4.1** to run the program. Select the splash screen or rainfall icon on the main tool bar, as shown in Figure 4.2. This will then take you to the Control Interface form.

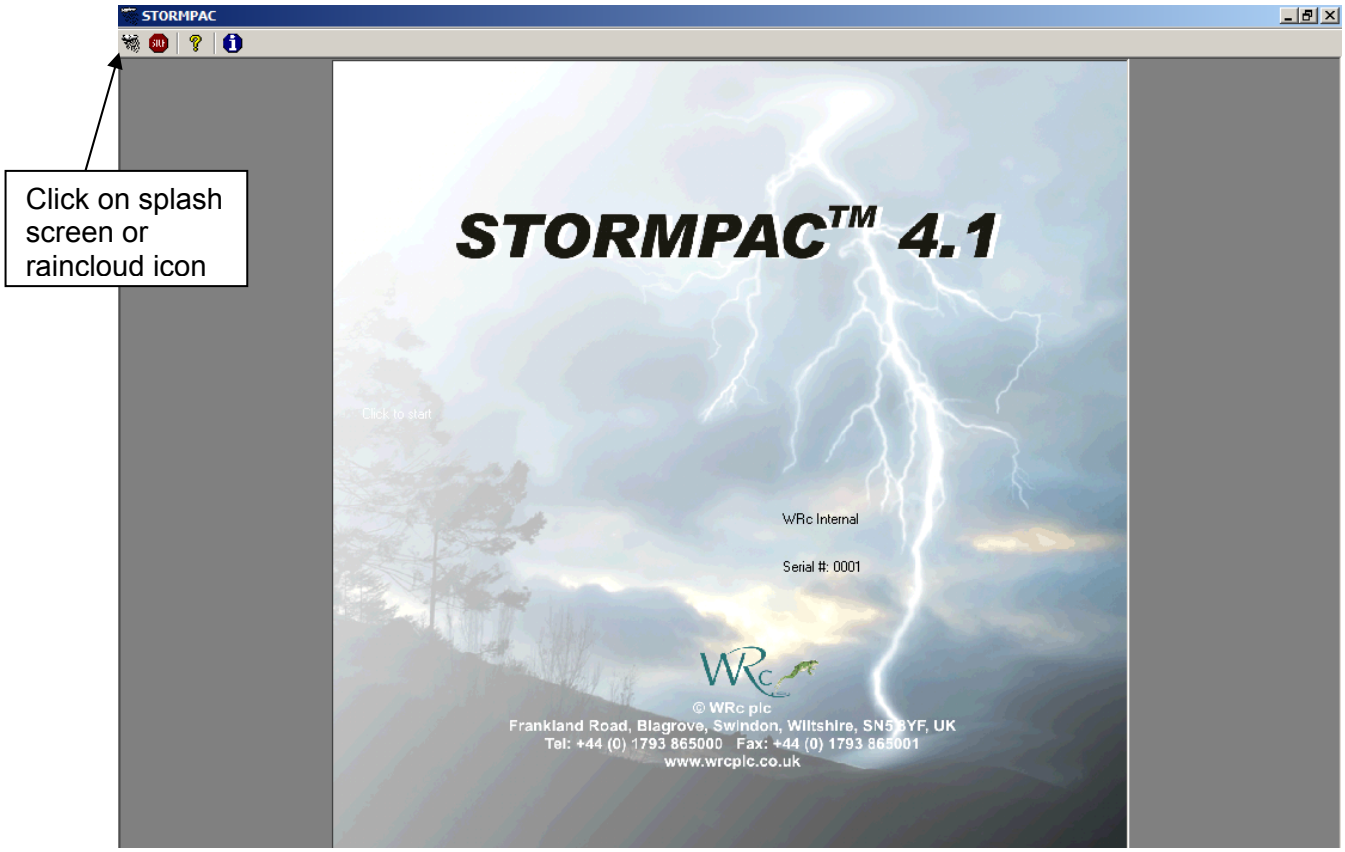
STORMPAC
Click on splash screen or raincloud icon
STORMPAC™ 4.1
Click to start
WRc Internal
Serial #: 0001
© WRc plc
Frankland Road, Blagrove, Swindon, Wiltshire, SN5 8YF, UK
Tel: +44 (0) 1793 865000 Fax: +44 (0) 1793 865001
www.wrcplc.co.uk

Figure 4-2 Splash Screen

The Control Interface form looks like the picture shown in Figure 4.3 – although it may not have all the buttons displayed, since the number of buttons that are displayed is a function of what data are present in your STORMPAC 4.1 database. The 'Country' drop down box is displayed first and this currently defaults to the UK. When STORMPAC is run for the first time after installation the initial window will ask you to specify the location of the "country.mdb" file. This database contains rainfall parameters specific to the UK. It will have been downloaded into the STORMPAC directory during installation. STORMPAC will store this location once specified. Future runs of the software will not bring up this window again and instead will go straight to the main menu as shown in Figure 4.4. It should be noted that country.mdb is very important to the calculations performed by STORMPAC. Therefore, take care not to delete it, otherwise it will be necessary to reinstall the file from the installation CD.

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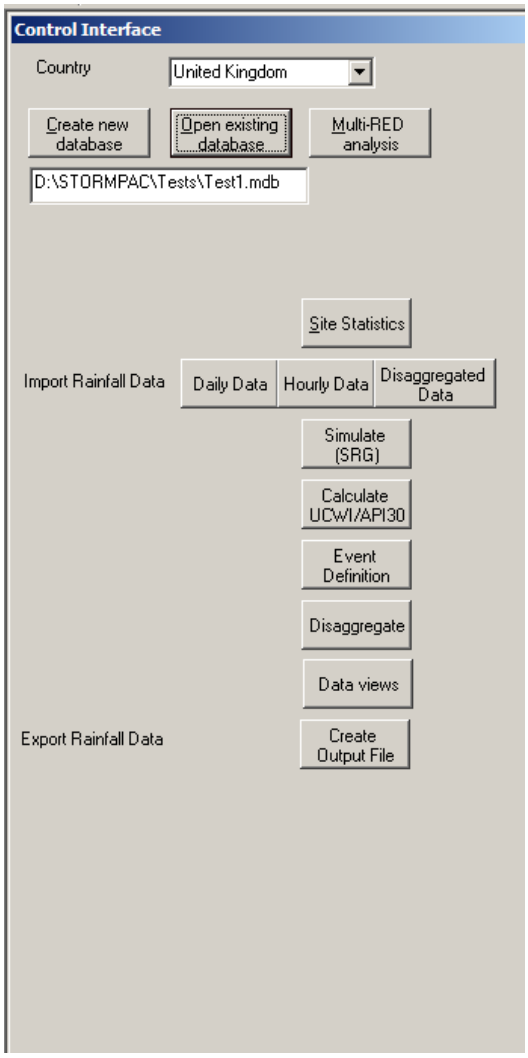

Figure 4-3 Control Interface Form

At this stage of the exercise the control interface will look like the following form:

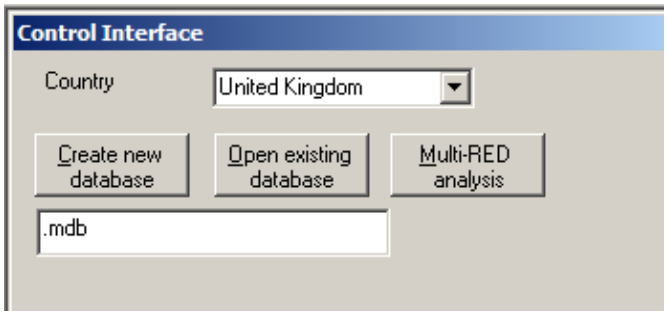

Figure 4-4 Control Interface Form During Runtime

You must now decide to open an existing STORMPAC database or create a new one. You will have to create a database during the first use of the software. Click the *Create database*

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button. This will display a Save As dialog box, and you can select a directory to save your database.

For this exercise select the *Create database* button.

4.4 Description of database tables

The STORMPAC 4.1 database contains the following tables:

Daily — This table contains a DateTime field (days) and a Depth field (mm). A chronological file of daily data is stored in this table if daily data have been imported.

Disagg — This table contains a DateTime field (5 minutes) and an Intensity field (mm/hr). 5 minute disaggregated data are stored in this table once they have been generated. Data are only stored between the start and end times of events as defined in the events table.

EventParam — This table contains the criteria used to define the events. The check boxes chosen and values used are recorded within this table. Also the number of events generated is updated as different filters are applied. The way in which the filtered events were last sorted is also recorded. A number will appear under the sorting parameter tab that will correspond to one of the parameters below.

- Time (event number) - 0
- Total event depth - 1
- Mean rainfall intensity - 2
- Maximum hourly rainfall intensity - 3
- Duration - 4
- Dry period - 5
- UCWI - 6
- API30 - 7

Sort order as ascending or descending is also recorded:

- Ascending - 0
- Descending - 1

Events — This table contains the statistics of the chosen events and is described in more detail in Section 5.4.

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General	This table contains various fields that describe the project you are currently working on, such as Project Title, Easting, Northing, Coastal Distance, Altitude, SAAR.
Hourly	This table contains a DateTime field and a Depth field (mm). A chronological file of historical hourly data is stored in this table if hourly data have been imported.
SMD	This table contains Date and SMD (mm) fields which records the imported SMD data for the catchment.
SMDParameters	This table contains the values used in SMD calibration as well as values used in UCWI and API30 calculations.
SRGData	This table contains a DateTime field (Hours) and a Depth field (mm). A chronological file of SRG hourly data is stored in this table if hourly SRG data have been generated.
SRGParameters	This table contains a SRGParameter field to store the calculated SRG parameters. These parameters are required if you wish to generate hourly SRG data.
UCWIandAPI30	This table contains DateTime (Hours), UCWI and API30 fields. UCWI and API30 values are stored here after they have been calculated. The evaporation value at each hourly step is also recorded here.

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Figure 4.5 shows what the database looks like when opened in MS Access 97.

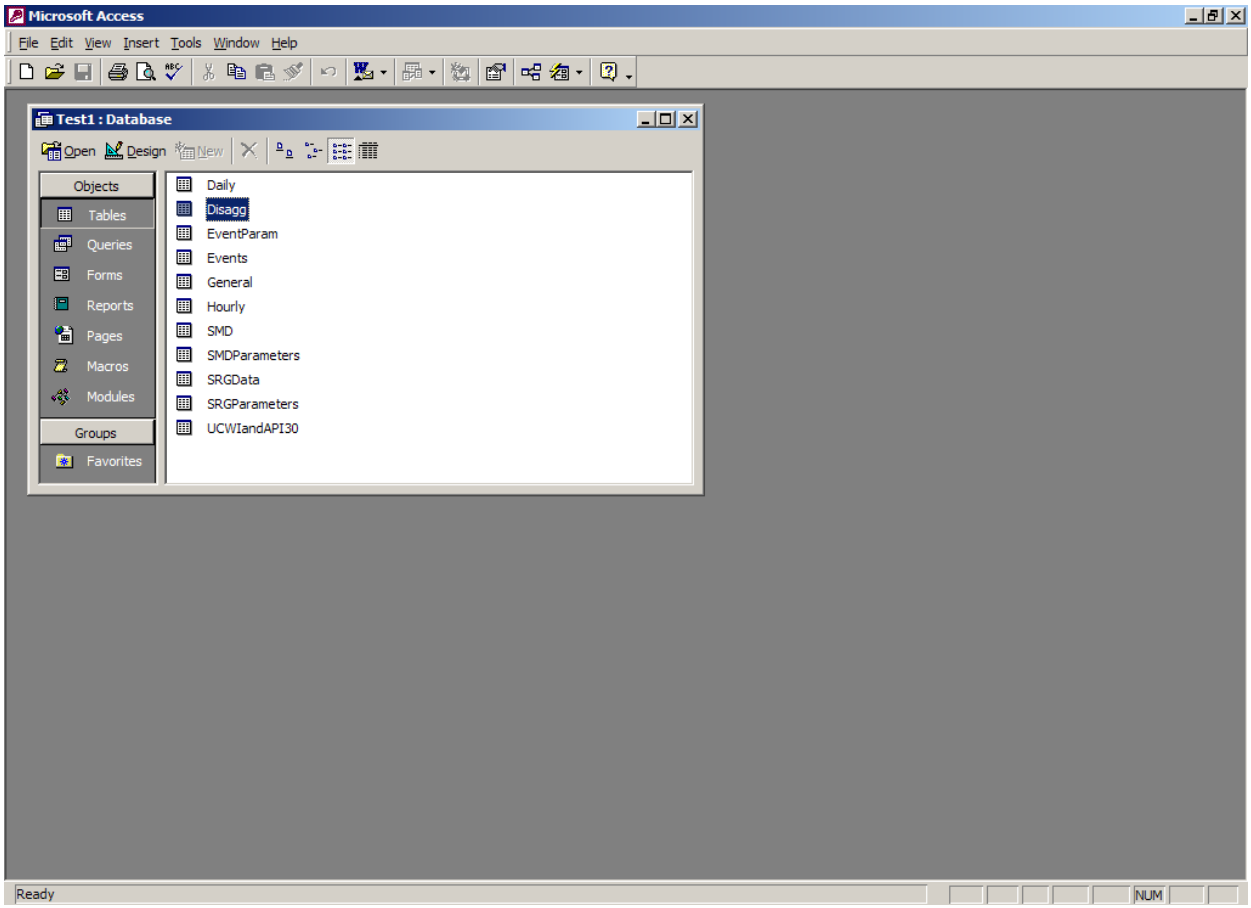

Figure 4-5 STORMPAC 4.1 Database

After saving your database you will be presented with the *Site Statistics* button and the import options of *Daily Data*, *Hourly Data* and *Disaggregated Data* buttons as shown in Figure 4.6.

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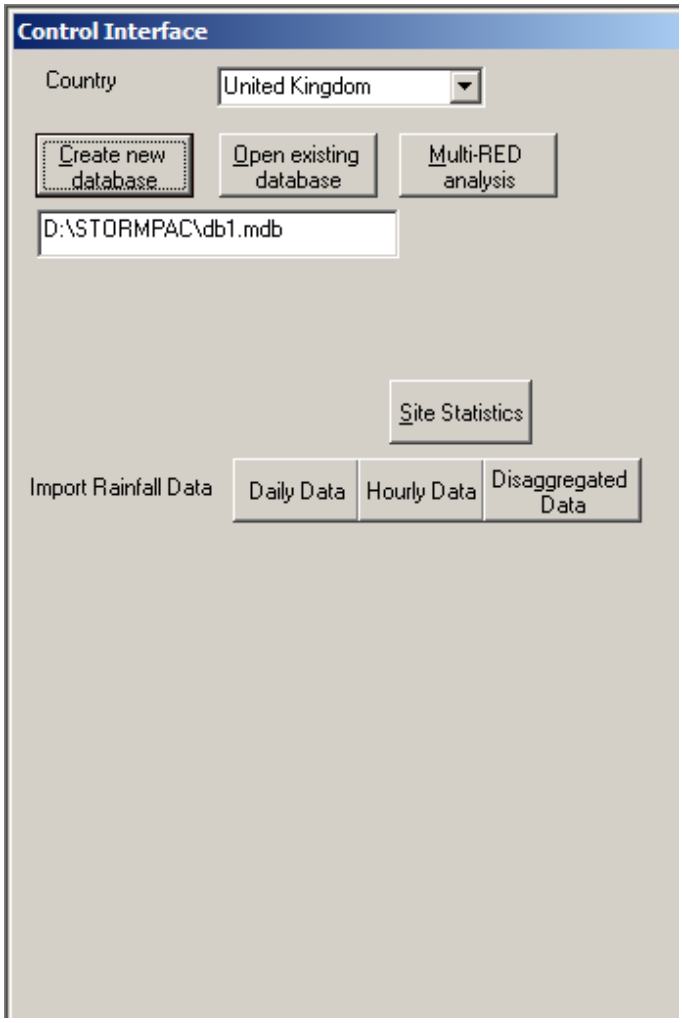

Figure 4-6 Control Interface Form during runtime

- If you click *Site Statistics* without first importing some data you will only be able to annually regionalise your rainfall series.
- However, if you import rainfall data as daily, hourly or disaggregated data (see Section 5 for a description of the different data formats) you will be given the options of annually or daily regionalising your data or, calculating statistics from your hourly historical data.
- UCWI values cannot be calculated until you have imported or generated some hourly data.

You have now reached step one as shown in Figure 4.1

4.5 Step 1 – Import Historical Hourly Data

The starting point for this exercise is historical hourly rainfall data. The example data files RAIN.SIM, SMD.XLS (supplied with STORMPAC) can be used for this exercise. Click on the *Hourly Data* button and find the file RAIN.SIM in the folder where STORMPAC was installed.

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Select the RAIN.SIM file and click *Open* to import the historical rainfall into your database. There should be one year of rainfall data in this file (year 1988).

When using other data files, it is important that they are in the correct format (see Section 5).

4.6 Step 2 – Calculate Site Statistics

The Site Information form is automatically displayed after importing the historical hourly rainfall data. You must fill all the boxes with the correct site information. This is important for the regionalisation element of the software. Select the correct Site Data Type to run the correct regionalisation routine, i.e. Annual or Daily; or it could be that you wish to import some historical hourly data. For this exercise select *Hourly Data* and fill in the form as illustrated in Figure 4.7. Then click *OK* to start the site statistics calculations and click *OK* on the message box that appears at the end of the calculations.

Clicking the Site Statistics button at any time during a STORMPAC session displays the Site Information form.

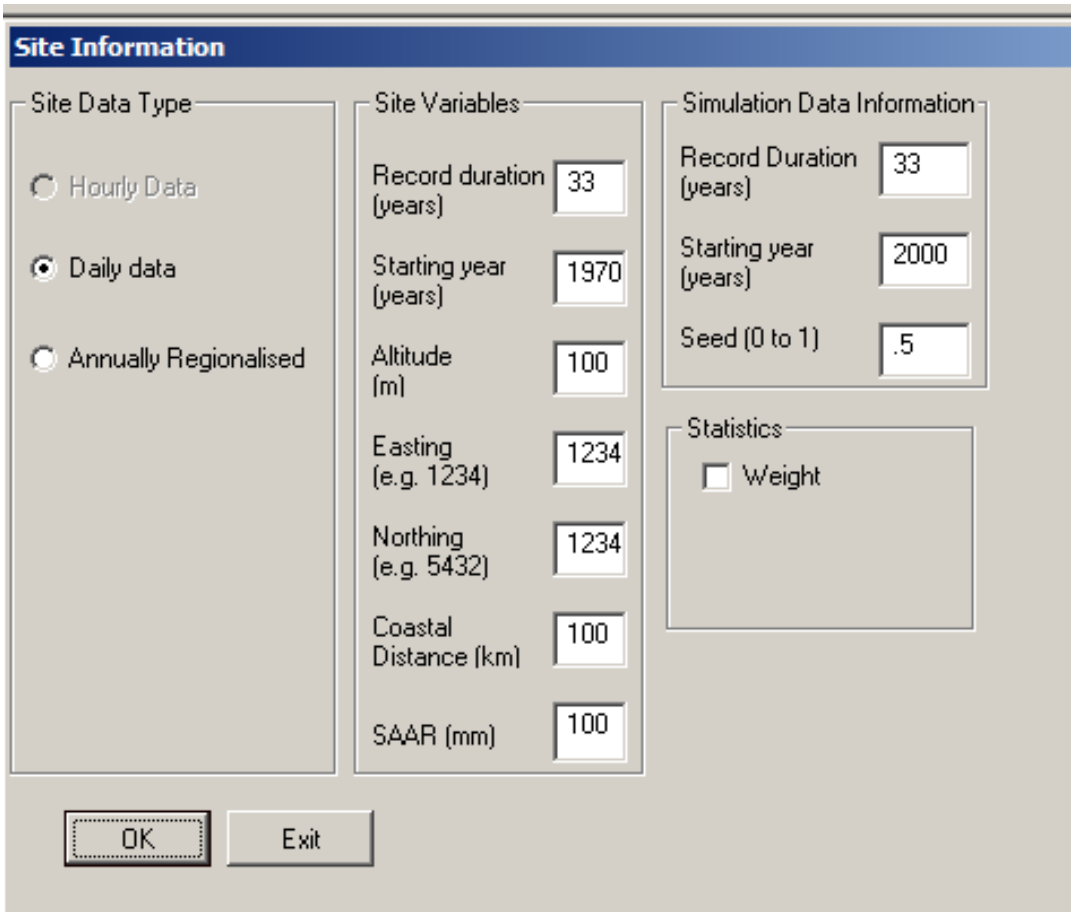

Figure 4-7 Site Information Form

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4.7 Step 3 – Calculate UCWI and API30 Values

To calculate UCWI and API30 values in STORMPAC, it is first necessary to calculate the SMD. The UCWI values are calculated on a continuous basis and not per event. This is achieved by calibrating a SMD model with the long-term average SMD data obtained for your study site. Click the *Calculate UCWI/API30* button on the Control Interface form to display the SMD Calculations form. The form is shown in Figure 4.8.

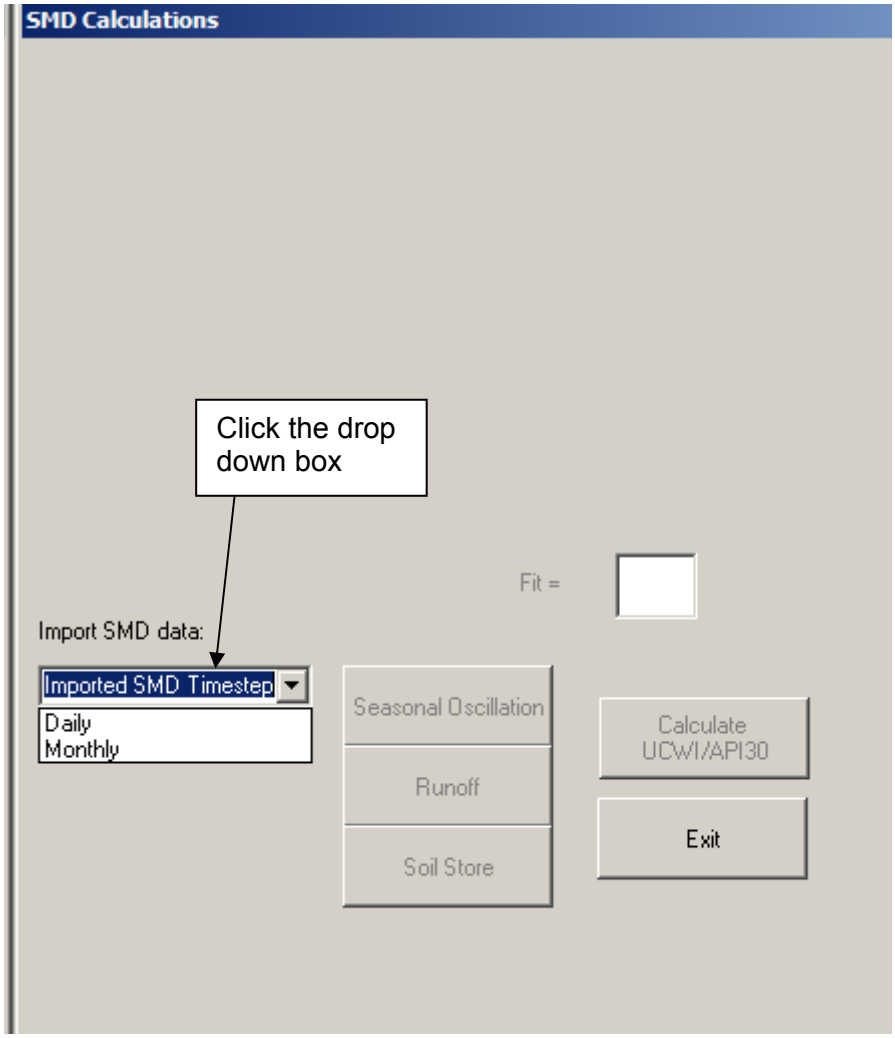

Figure 4-8 SMD Calculations Form

First determine the time step of your SMD data by selecting either *Daily* or *Monthly* from the Import SMD data drop down box. For this exercise, select *Monthly*. Find the example SMD.XLS file using the Open Import File dialog box, select the file and press Open. The data will then be imported. Click *OK* on the message box that appears at the end of the import. The monthly long-term average SMD data are then displayed on the form along with the SMD values calculated using default parameters. The SMD Calculations form should now look like Figure 4.9. Change the colours on the SMD graph by clicking on the chart labels.

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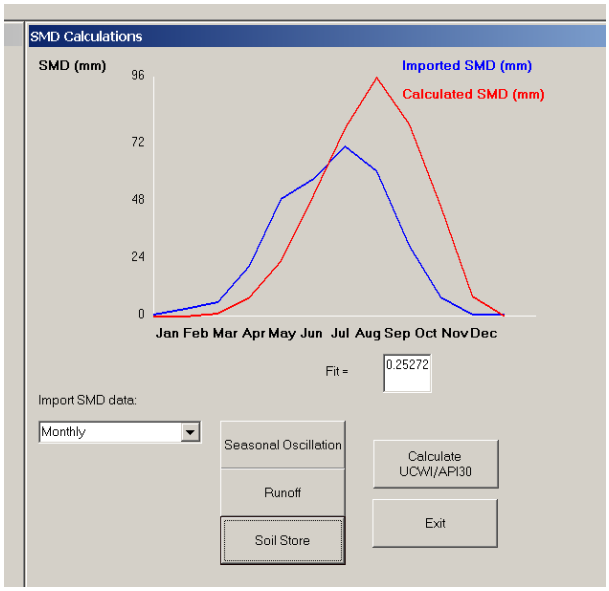

Figure 4-9 SMD Calculations Form during run time

Now calibrate the SMD model by changing the model parameters until a good fit is achieved between the calculated and imported SMD data. To assess the goodness of fit you need to select the *Compare* check box. This will display the goodness of fit factor in the *Fit =* box. Section 7 describes the SMD model in more detail and describes which parameters should be changed.

With this exercise, and future runs of STORMPAC, it is recommended to click the *Seasonal Oscillation* button first and change the F, A or x parameters (described in Section 7) since these have the most significant impact on the shape of the SMD curve. By clicking on the *Seasonal Oscillation* button the form shown in Figure 4.10 will be displayed.

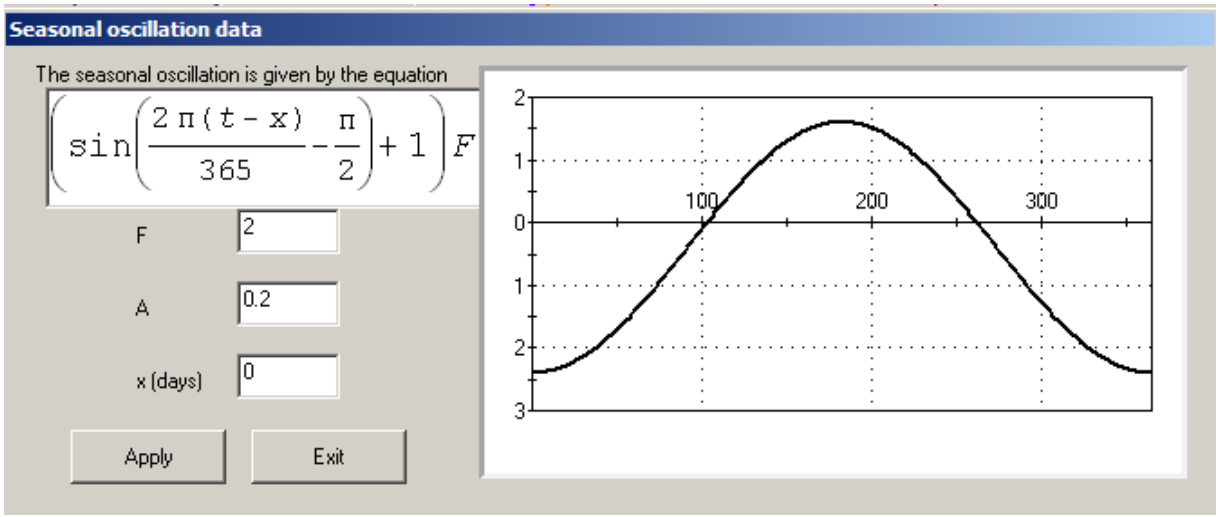

Figure 4-10 Seasonal Oscillation Data Form

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Try selecting a new set of different values for these parameters and the shape of the plot will change after you click *Exit* on the Seasonal Oscillation form. Click the *Seasonal Oscillation* button again to try different parameters. Clicking *Exit* will change the plot again. If the *Compare* check box is selected the goodness of fit factor will also change with each plot change.

For the purposes of this exercise, input the following parameters:

F = 1.9

A = 0.8

X = 0

This will give a goodness of fit value of 0.9902. This indicates a very good fit. Therefore, there is no need to change any of the other parameters. However, click on the *Runoff* button and change the parameters if you wish; this form is shown in Figure 4.11.

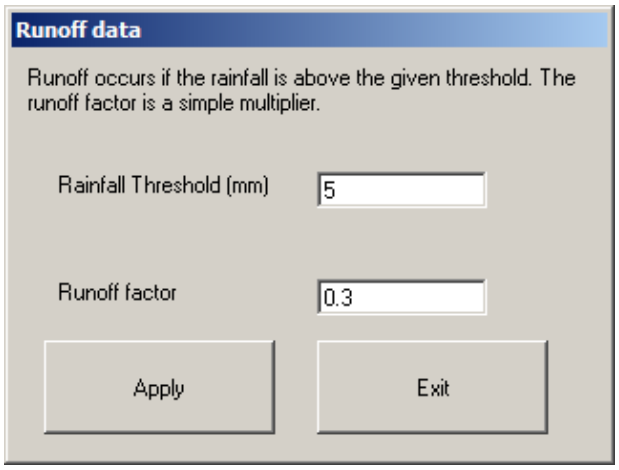

Figure 4-11 Runoff Data Form

Again, try selecting different values for the Rainfall Threshold and Runoff Factor and clicking *Exit* will cause the plot and goodness of fit to change.

The final way to change the calibration is to click the *Soil Store* button. This will display the form shown in Figure 4.12.

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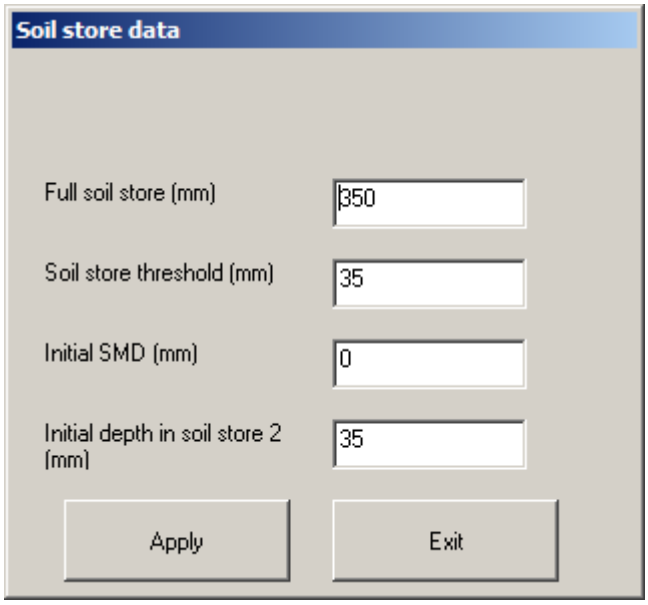

Figure 4-12 Soil Store Data Form

It is usual to achieve a good calibration by changing the parameters on the Seasonal Oscillation form only. However, you can fine-tune the calibration with the parameters on the Soil Store data form. Typically, achieving a goodness of fit value more than 0.9 signifies a good calibration. However, the sensitivity of the calculated UCWIs and API30s to the fit of the SMD curve is not that critical, therefore, do not worry if your fitness value is less than 0.9.

To calculate UCWI and API30 values click the *Calculate UCWI/API30* button on the SMD Calculations form and the UCWI / API30 calculation data form as shown in Figure 4.13, is displayed.

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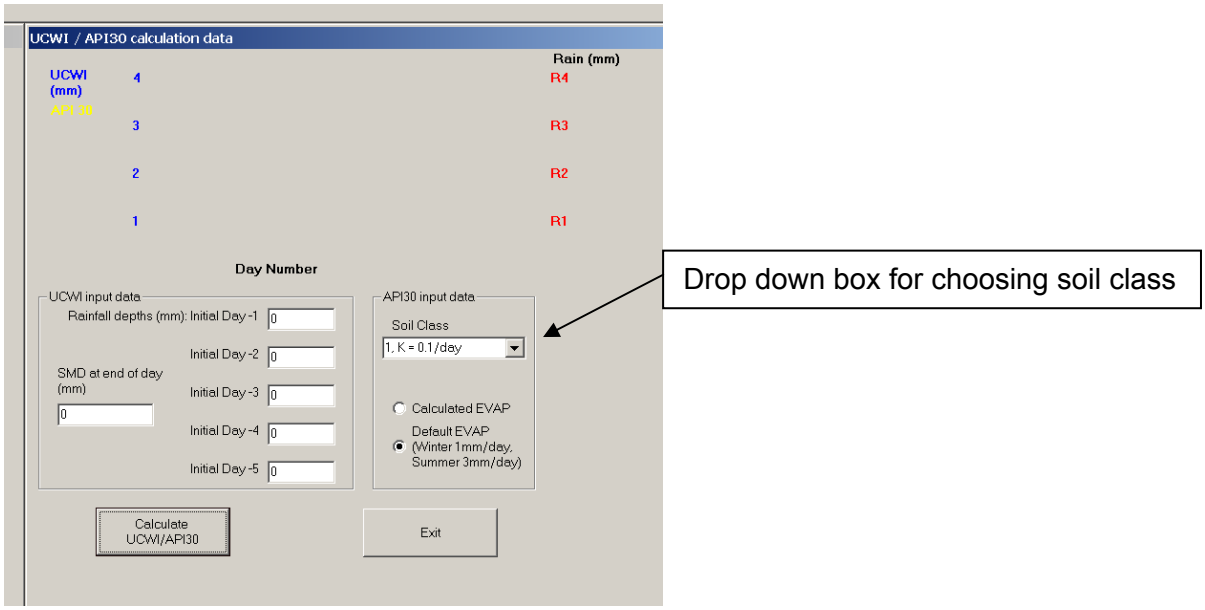

Figure 4-13 UCWI / API30 Calculation Data Form

STORMPAC calculates UCWI as described in the Wallingford Procedure, Chapter 7.9[4].

UCWI = 125 + 8(API5) – SMD

Therefore, as API5 depends on the previous 5 days' rainfall you are required to input the 5 daily rainfall values prior to the start time of your hourly rainfall data in the boxes marked *Initial Day -1* to *Initial Day -5*. This represents the first day to the fifth day before the start of your hourly rainfall data respectively. You are also required to enter the SMD at the end of the day in the *SMD at end of day* box. We suggest that you use the following values:

INITIAL DAY –1 = 0

INITIAL DAY –2 = 0

INITIAL DAY –3 = 0

INITIAL DAY –4 = 0

INITIAL DAY –5 = 0

SMD AT END OF DAY = 0

API30 values are calculated using the method described in WaPUG User Note 28[9]. You must choose the soil class from the drop down box and then decide whether you want to use default evaporation parameters, of 1 mm/day in Winter and 3 mm/day in Summer, or the evaporation values that you have just calculated during the SMD calibration stage. For this exercise use the default values of Soil Class 1 and Winter 1 mm/day, Summer 3 mm/day.

After these boxes have been filled in click the *Calculate UCWI/API30* button to start the calculations.

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If data exist in the database you will be asked “Do you want to overwrite existing UCWI/API30 data”. Clicking *Yes* will overwrite the UCWI data in your database, whilst clicking *No* will cause the UCWI Calculation data form to unload.

On clicking *Yes*, a plot of the calculated UCWI, API30 and rainfall will be displayed after the calculations have finished along with a message box stating: *“Do you want to continue?”.* The purpose of the plot is to provide the user with a visual plot of the UCWI and API30 values in relation to the rainfall. Confirm that when rainfall values increase the UCWI values increase as well.

Clicking *No* will take you back to the UCWI Calculation data form where you will be allowed to re-enter the preceding five-day rainfall and SMD at end of day values. Clicking *Yes* means that the UCWI data will be written to the database. Click *Yes* for this exercise.

Click *OK* on the message box stating UCWI/API30 Calculation Complete and then *Exit* on the UCWI Calculation data form to return to the Control Interface form.

We have now reached step 4 on Figure 4.1.

4.8 Step 4 – Define Rainfall Events

You are now in a position to define some events from your historical hourly database. This is achieved by clicking on the *Event Definition* button on the Control Interface form. The Storm Event Definition form, shown in Figure 4.14 is displayed.

STORMPAC identifies each event within the hourly rainfall record that meets the criteria that the user defines on the Storm Event Definition form. As described in Section 5.4 you can filter the events from your hourly historical record by choosing event depth, mean rainfall intensity or maximum hourly intensity. You must specify a *minimum inter event dry period (hours)* to identify individual storm events. The minimum inter event dry period can range in value from 1 to the maximum number of hours in your hourly historical database.

Ensure the correct data type is selected at the top of the form: Historical or Simulated, in this exercise *Historical* should be selected.

For the purposes of this exercise you are required to put a value of 1 in the *minimum inter event dry period* box, this will identify all storms in your historical database. Also, because you want to sort by depth, you should select the *Depth* option in the Sort Criteria window and the Descending option, which will sort the database by depth in descending order (i.e. the event with the largest depth will be the first record in the database). You should also select the *Select only in Bathing Season (May to Sept)* checkbox since we require events in the bathing season only for this example.

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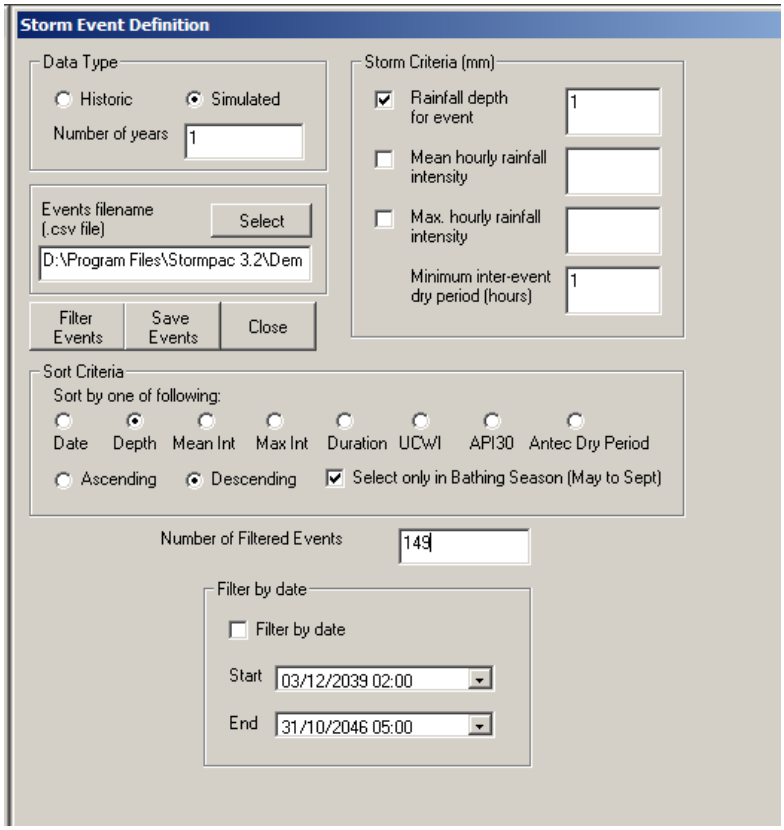

Figure 4-14 Storm Event Definition Form

Now click the *Filter Events* button and a progress bar and event counter will appear. After completion a message box will appear stating “Events table successfully generated”. Click *OK* and another form is displayed on top of the Control Interface form, which shows the events as they are stored in the database.

At this point you could select different sorting criteria or different storm criteria (specifically the rainfall depth, mean hourly rainfall intensity and maximum hourly rainfall intensity). This changes the order of the events in the database.

To save your set of events select a destination for the CSV file that will contain statistics of the filtered and sorted events (by clicking the *Select* button) and, if required, enter a new file name in the *Save Event Data As* dialog box. To produce the CSV file click *Save Events*.

If you wish to change the number of events saved in the database you have to select a different minimum inter event dry period. You are warned before you do this so that you cannot overwrite the full list of events in error.

Click *Close* to return to the Control Interface. We have now reached step 5.

4.9 Step 5 – Disaggregate Hourly Data

To disaggregate the data you have to click the *Disaggregate* button on the Control Interface form. The Hourly Rain Disaggregator form, as shown in Figure 4.15 will be displayed.

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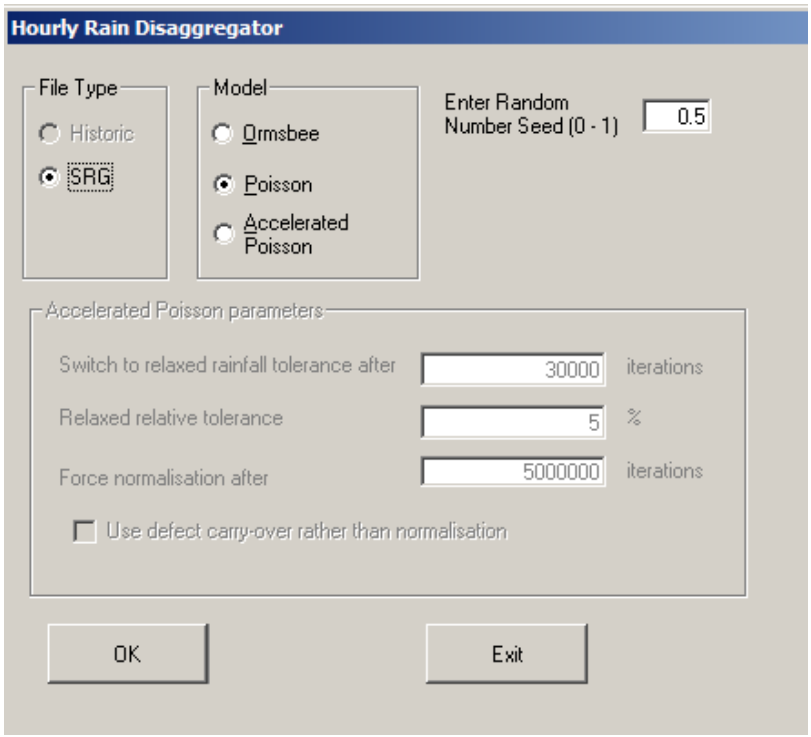

Figure 4-15 Hourly Rain Disaggregator Form

Select the *Historical* option to make sure the hourly historical rainfall is disaggregated. If simulated rainfall data was to be disaggregated the SRG option should be selected. Also select the Poisson option to use the new Poisson rectangular pulses dissaggregator. This should be checked by default and we recommend that this should always be used as it replicates five minutely data sets to a higher standard than the Ormsbee method particularly for extreme values. The Ormsbee method should only be used to replicate sets of rainfall created in previous versions of STORMPAC (up to and including 3.1) and here the Ormsbee option needs to be selected. Click *OK* when the correct file type and disaggregator required have been selected.

A progress bar will appear informing the user that the disaggregation calculation is proceeding. Once completed, the user is returned to the Control Interface form. The data has been disaggregated to five minute interval values.

You are now in a position to export the disaggregated data to HydroWorks/InfoWorks.

To stop a disaggregation that is taking too long to process click the *Cancel* button.

If a dataset of 10 years takes several hours to process, and you want to speed up the process click the *Cancel* button and select the *Accelerated Poisson* option and Click *OK*. If this processing takes too long then click the *Cancel* button and reduce the first or second iteration values to speed up the disaggregation. See section 2.3.3 for details.

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4.10 Step 6 – Create Output File

To export data to a HydroWorks file click the *Create Output File* button on the Control Interface form. The File Export form will appear as shown in Figure 4.16.

You can save data to either a HydroWorks single events file or a HydroWorks multiple events file by selecting the appropriate boxes. Also, you can save the API30 values in the same .RED files as the UCWI values if you select the *include API30 values* checkbox.

For the purposes of this exercise, we require the top 10 storms sorted by depth. We have already sorted the storms in descending order. To select the top ten you have to enter 10 in the *Max No of Single Events to be exported* box and select the *Export Single Event Files* check box.

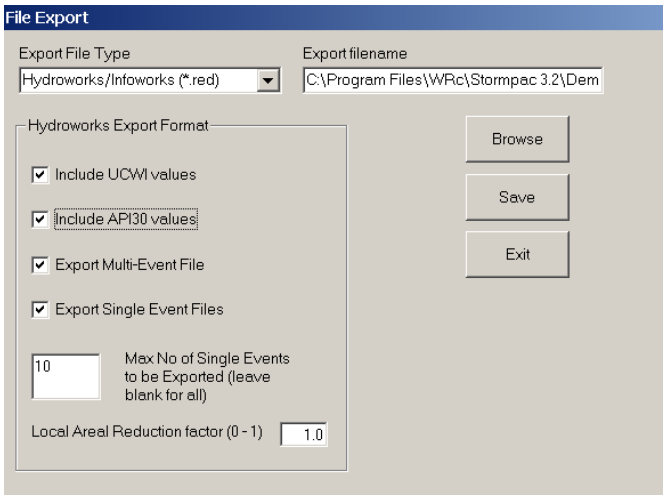

Figure 4-16 File Export Form

Click *Browse* to select where the exported files will be saved and to name the files. The export filenames that are created will contain the event number as well as the filename you specified. The filename defaults to the same name as that specified on the Storm Event Definition form. For example choosing the filename 'Storm' results in the following filenames for our 10 storms Storm001.RED, Storm002.RED.….Storm010.RED.

Click *Save* to save the files to the specified directory, next, click *Exit* to exit the File Export form and then click *STOP* on the main menu bar to exit STORMPAC.

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5. USER INPUTS NECESSARY FOR STORMPAC

Introduction

This section describes all of the different types of input necessary for STORMPAC. The data inputs are divided into the following separate sub-sections.

5.1 Historical hourly rainfall processing
5.2 Regionalisation and processing of SRG data
5.3 Soil moisture deficit data
5.4 The event file
5.5 WASSP PCD files

The likely source of these data and the formats necessary for STORMPAC to import them are described.

5.1 Historical hourly rainfall data

5.1.1 Source

Digitised hourly data are available for approximately 200 UK sites and may be obtained on disk from:

The Meteorological Office

FitzRoy Road
Exeter
Devon
EX1 3PB
United Kingdom

Tel: 0870 900 0100, or +44 (0) 1392 885680 from outside the UK

Fax: 0870 900 5050, or +44 (0) 1392 885681 from outside the UK

website: www.metoffice.gov.uk

e-mail : enquiries@metoffice.gov.uk

Other local sources for data include, for example, Water Utilities, Local Authorities, The Environment Agency in England and Wales, SEPA in Scotland and EHS in Northern Ireland.

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5.1.2 Selection

Selection of the most appropriate gauge site should, if appropriate, be carried out in consultation with the Met. Office. The following factors should be borne in mind:

- Distance of the gauge site from the catchment,
- Local rainfall variation (consult rainfall maps in Volume 3 of the Wallingford Procedure 5 or the Flood Estimation Handbook[17]).
- Length of record available (see below).
- Periods of missing data.
- Format of the data (see below).
- Cost of the data.

5.1.3 Length of record

The accuracy of the rainfall event statistics will be affected by the record length used. This is particularly important when considering extreme events. The recommended record length is 10 to 20 years. However, some design criteria may require longer records to include more extreme events.

5.1.4 Format of data – Met. Office

Potentially, historical hourly rainfall data may be provided in several different formats depending on whether they are from the Met. Office and the age of the data. A full explanation of the format is provided with any data supplied by the Met. Office.

5.1.5 Format of data – STORMPAC

STORMPAC has the capability to import a variety of hourly file types. These are .**TAB**, .**DAT**, .**SIM**, .**SCF**, .**HIS** and .**STM**. Files are imported into the working project database in the Hourly table. This consists of 2 fields: the date/time data and the rainfall depth data. The following describes each of the import file formats.

5.1.5.1 . TAB and .DAT tab de-limited files

This is a file format for hourly rainfall data used by WRc an example file is included with the installation. The files are tab de-limited file with 5 columns that contain the following data:

Column 1: Year

Column 2: Month

Column 3: Day

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Column 4: Hour

Column 5: Rainfall intensity (mm/hr)

5.1.5.2 . SIM files

This is the common format for hourly rainfall files used in STORMPAC (see Table 5.1). This format has one row per 24 hours containing the year, month and day, followed by two more rows containing the hourly rainfall depths (12 hours on each row).

It is essential that the historical hourly data are input exactly in the following format for STORMPAC to read these data correctly:

Line 1: YEAR, MONTH, DAY

Format: 10 spaces, four digits for the YEAR (e.g. 1999), 5 spaces, 2 digits for the MONTH (e.g. 08), 5 spaces, 2 digits for the DAY (e.g. 04).

Line 2: HOUR 1, HOUR 2, HOUR 3…..HOUR 12

Line 3: HOUR 13……HOUR 24

Format: 3 spaces, real number with one decimal place (dp), 3 spaces, real number with 1dp

Each real number must take up 4 spaces e.g. (12.4, 02.4) but the leading zero may be omitted e.g. (<space>2.4).

These files may represent either historical data or data from the SRG in STORMPAC.

5.1.5.3 .SCF files

The first three rows give information about the gauging station name and location. Row 4 contains column headings. Rainfall data follows with one data point per row. At the end of the file definitions of “Quality” values given. An example of this format can be seen in Table 5.2:

Line 1: “Gauge reference”

Line 2: “Met. Office Gauge reference”

Line 3: “Station name”

Line 4: “Year, Month, Day, Hour, Minute, Second, Rainfall, Quality"

Line 5 to end of data: Comma separated data corresponding to order of headings

Beyond last line of data: Definitions for “Quality” values

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5.1.5.4 HIS files

Same format as **.SIM** files.

5.1.5.5 .STM files

These are events output files from STORMPAC2. STORMPAC 4.1 extracts the hourly rainfall data and corresponding dates. To ensure a continuous hourly rainfall series zero values are inserted for all hours between events. The hourly time series can then be used to redefine events or create output files. An example of this format can be seen in Table 5.3.

5.1.6 Missing data

Missing data points are expected to take the form of either –999, -99999 or 99999. If these values are imported from any file format zeros are substituted at the relevant date/time position. An error message will appear stating a gap has been found if there are any chronological gaps in the rainfall data from a .SCF file. The import process will then continue. Once complete, however, the user should correct the fault in the data and reload the file into STORMPAC before performing any further analysis. Careful consideration should be given to missing data within the data file. These values need to be edited to show 0.0 although a 'global' search and replace is not recommended. The most prudent procedure to follow is to scrutinise the file at the point where a missing data value occurs and then decide if the insertion of a 0.0 will affect the event selection. For example, if a series of missing data values occur because of a gauge failure lasting for several weeks, a series of zero values will only distort the total number of events and not any individual storm. However, if a missing data value occurs in the middle of a storm and a zero value is inserted STORMPAC will interpret this as two events, if the minimum inter-event dry period is set at 1. In this situation, it may be necessary to omit the whole event (i.e. edit the rainfall to zeros). Clearly, the final decision will depend on what the data are to be used for. However, you should guard against producing a rainfall file which could be misinterpreted by future users.

5.1.7 Estimated rainfall

The Met. Office show estimated rainfall as negative values. These should be edited to show either true rainfall or zero rainfall. Again, careful scrutiny of the data should be made before editing is carried out.

5.1.8 Leap years

STORMPAC does not require any editing of rainfall data with respect to leap years.

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Table 5.1 Example of .SIM and .HIS Formats for Hourly Rainfall Data

```
     2000    1    1
 0.0   0.0  0.2  1.2  2.3  2.2  1.7  0.8  0.1  0.0  0.0  0.0
 0.0   0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
     2000    1    2
 0.0   0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0   0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.2  2.0
     2000    1    3
 2.0   6.0  2.3  2.2  1.7  1.3  0.0  0.0  0.0  0.0  0.0  0.0
 0.0   0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
     2000    1    4
 0.0   0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0   0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
     2000    1    5
 0.0   0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0   0.0  0.0  0.0  0.0  0.0  0.0  0.2  0.1  0.7  1.4  1.3
     2000    1    6
 1.2   0.2  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0   0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
     2000    1    7
 0.0   0.1  0.3  0.2  0.0  0.0  0.0  0.0  0.0  0.0  2.4  1.3
 0.0   0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
     2000    1    8
 0.0   0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0   0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
     2000    1    9
 0.0   0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0   0.0  0.9  0.3  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
     2000    1   10
 0.0   0.0  0.0  0.0  0.0  0.0  1.7  2.7  1.7  1.1  1.4  0.9
 0.8   0.9  1.3  0.7  0.7  0.7  0.6  0.3  0.1  0.1  0.0  0.0
```

Format:

line 1:	xxxxxxxxxx2000xxxxx_1xxxxx_1
line 2:	xxx_0.0xxx_0.0xxx_0.2xxx_1.2xxx_2.3xxx_2.2xxx_1.7xxx_0.8xxx_0.1xxx_0.0xxx_0.0xxx_0.0

Key:

2000	Year
1	Month
10	Day
x	Space
_	Space for extra digit if required
0.8	mm rainfall hour 13

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Table 5.2 Example of .SCF Format for Hourly Rainfall Data

GAUGE REF. ,"562150"
M.O. GAUGE REF.,"562150"
STATION NAME ,"Wayoh Res. No.2"
Year, Month, Day, Hour, Minute, Second, Rainfall, Quality
1993, 1, 2, 0, 0, 0, 0.000, 8
1993, 1, 3, 0, 0, 0, 0.000, 12
1993, 1, 4, 0, 0, 0, 0.000, 12
1993, 1, 5, 0, 0, 0, 0.000, 12
1993, 1, 6, 0, 0, 0, 0.000, 12
1993, 1, 7, 0, 0, 0, 0.000, 12
1993, 1, 8, 0, 0, 0, 0.000, 12
1993, 1, 9, 0, 0, 0, 0.000, 12
1993, 1,10, 0, 0, 0, 0.000, 12
1993, 1,11, 0, 0, 0, 0.000, 12
1993, 1,12, 0, 0, 0, 0.000, 12
1993, 1,13, 0, 0, 0, 0.000, 12
1993, 1,14, 0, 0, 0, 0.000, 12
1993, 1,15, 0, 0, 0, 0.000, 12
…….
…….
…….
1997,12,20, 0, 0, 0, 9.800, 12
1997,12,21, 0, 0, 0, 0.000, 0
1997,12,22, 0, 0, 0, 0.000, 0
1997,12,23, 0, 0, 0, 0.000, 0
1997,12,24, 0, 0, 0, 3.700, 12
1997,12,25, 0, 0, 0, 9.300, 12
1997,12,26, 0, 0, 0, 11.900, 12
1997,12,27, 0, 0, 0, 28.700, 12
1997,12,28, 0, 0, 0, 10.900, 12
1997,12,29, 0, 0, 0, 9.400, 12
1997,12,30, 0, 0, 0, 7.300, 12
1997,12,31, 0, 0, 0, 4.800, 12
1998, 1, 1, 0, 0, 0, 17.000, 12
Quality Types : , 0 = Good , 2 = Edited, 3 = Snow, 4 = Suspect, 8 = Missing
Man. Entered Quality Types : , 10 = Good, 12 = Edited, 13 = Snow, 14 = Suspect, 18 = Missing
Dig. Quality Types : , 20 = Good, 22 = Edited, 23 = Snow, 24 = Suspect, 28 = Missing
M.O. Quality control : , 30 = Good, 32 = Edited, 33 = Snow, 34 = Suspect, 38 = Missing

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Table 5.3 Example of .STM Format for Hourly Rainfall Data

```
RAINFALL EVENT FILE

  Filename: dum.STM
  Location: dum
  Number of years: 10
  Hourly rainfall file: dum.sim
  SMD file: system.smd


 Event selection criteria (events satisfy all four criteria)

 1 Total rainfall depth > or =  1.00 mm

 2 Mean rainfall intensity > or =   .10 mm

 3 Max hourly rainfall intensity > or =   .10 mm

 4 Dry period defining end of event > or = 1 hours
```

	YEAR	M	D	ST TIM	DRN hrs	TOTAL DEPTH mm	MEAN INT mm/hr	MAX HRLY INT mm/hr	UCWI	ANTEC	ANT DRY PRD hrs	VALUES IN EVENT PER HOUR (mm)		
*****														
1	2000	1	2	12	5	2.5	.5	1.2	124	1	35	.5	1.2	.1
2	2000	1	2	24	9	3.2	.4	1.1	139	1	7	.2	1.1	.8
3	2000	1	7	17	10	5.9	.6	1.6	126	1	94	.7	.4	.6
4	2000	1	8	19	5	4.2	.8	2.1	141	1	16	.2	.7	1.1
5	2000	1	9	7	7	4.1	.6	1.2	162	0	2	.2	.5	.7
6	2000	1	9	18	7	8.1	1.2	1.2	178	1	4	1.0	1.2	1.2
7	2000	1	11	16	4	2.0	.5	.9	153	1	39	.2	.9	.6
8	2000	1	13	19	3	1.5	.5	.8	133	1	42	.3	.8	.4

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5.2 Regionalisation and processing of SRG data

5.2.1 Simulated hourly rainfall data

Location

The SRG will output an hourly rainfall time series for any location within the UK.

Length of record

The SRG can simulate up to 100 years of data. It is recommended that at least 20 years of simulated data are used to ensure that the output provides a statistically representative series. When working with historical data, the maximum length of data series which can be imported is 50 years.

Format of data

The output from the SRG populates the SRG Data table in the working project database. The format is the same as that described for historical data in Section 5.1.5.

5.2.2 Essential catchment location parameters

These are required before the SRG can proceed. STORMPAC will direct the user to the site parameters input page if it has not been already populated. Once entered, the SRG parameter data will be stored in the project database and will be available if the project is subsequently re-opened for further analysis.

Location input

To regionalise the SRG some local catchment and geographical input details are required. Essential inputs include: grid reference, distance from coast (km) and altitude of study catchment (m).

Sources and formats

Grid reference: A 4 figure easting and northing grid reference is required for the local catchment. The first number, relating to the National Grid sheet reference can be obtained from an ordnance survey (OS) map or by looking at Figure 5.1 and selecting the value that corresponds to the study catchment. It should be noted that the map shown only provides the first figure of the each 4 figure grid reference. The remaining three figures are obtained from an OS map. The range of grid reference values that STORMPAC recognises is shown in Table 5.4. If the site under consideration is outside the allowable range, STORMPAC will generate a warning message to inform the user. However, the SRG parameters will then still be calculated using an extrapolation procedure. It should be noted that the resulting SRG parameters may not be as reliable as ones calculated for sites within the allowable range.

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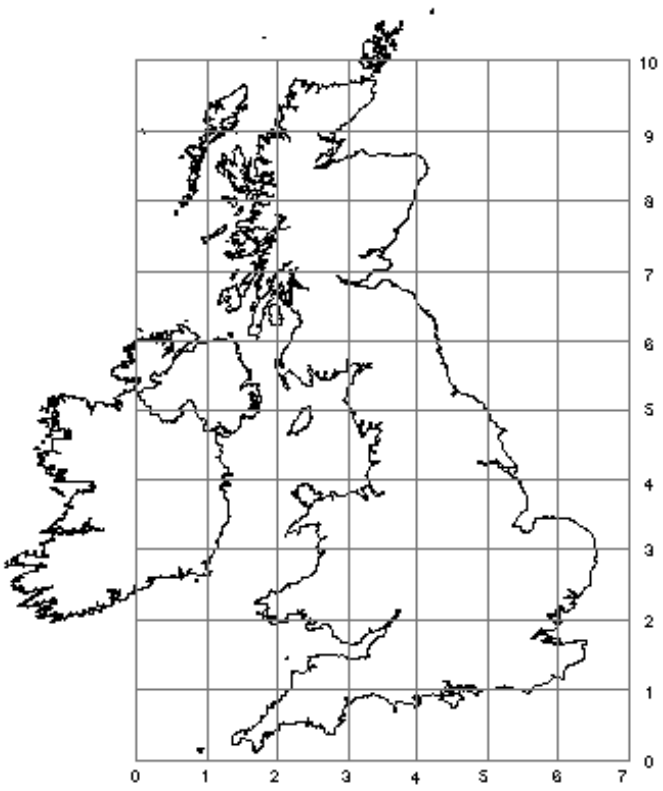

Figure 5-1 Map of the UK to Identify the First Figure of the Northing and Easting Grid Reference for the Study Catchment

Distance from coast. Obtain this value from an OS map. STORMPAC needs this value in rounded whole kilometres. The range of distances that STORMPAC recognises is shown in Table 5.4. STORMPAC will generate a warning message to inform the user if the site under consideration is outside the allowable range.

Altitude. The average altitude of the study catchment should be obtained from an OS map and should be recorded in metres. The allowable range that STORMPAC operates within is given in Table 5.4. STORMPAC will generate a warning message to inform the user if the site under consideration is outside the allowable range. It is likely that unreliable results will be produced using the Annually Regionalised SRG for catchments above this range. Therefore, it is recommended that historical rainfall should be used in this situation.

Table 5.5 Allowable Ranges for Site Parameters

Site Parameter	Minimum Value	Maximum Value
Easting	0600	6470
Northing	0642	8462
Distance from coast (km)	0	145
Altitude (m)	0	381

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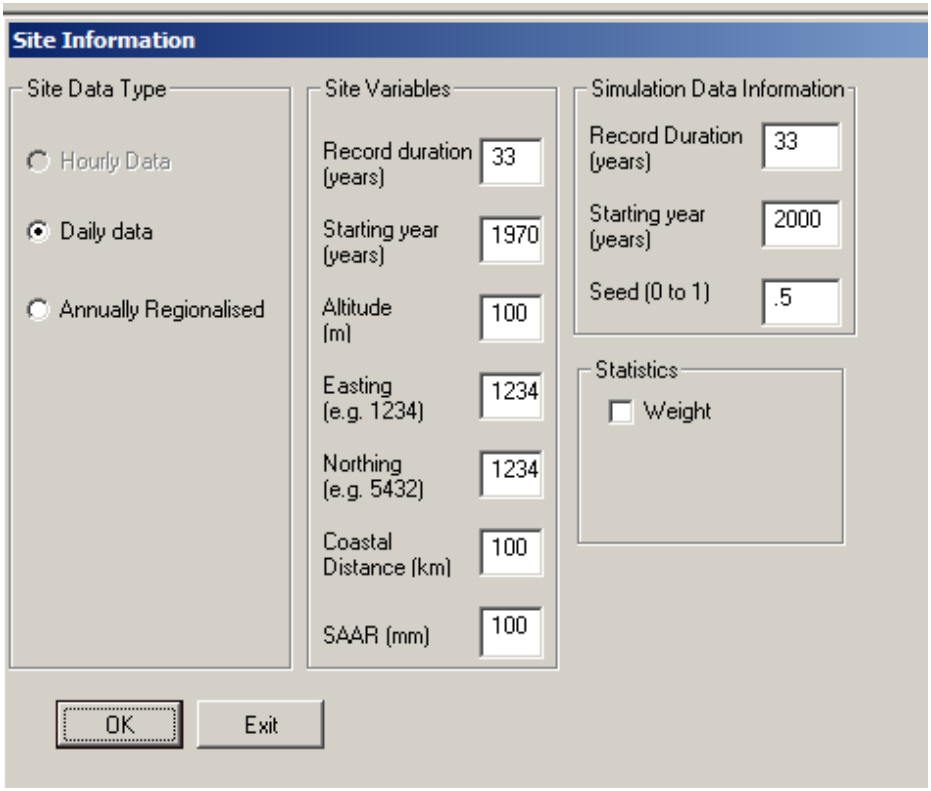

Figure 5-2 Site Parameters from STORMPAC

5.2.3 Historical daily rainfall data

Daily rainfall

Either historical daily rainfall data or the average annual rainfall values are necessary to aid regionalisation of the SRG. Historical daily rainfall data are discussed here. The standard average annual rainfall (SAAR) value is discussed in the next section (5.2.4).

Source

Digitised daily data are available for an extensive number of sites covering much of the UK. These data are obtainable from the Met. Office (see Section 5.1 for the address), although local sources such as Water Companies or Local Authorities may also have this information.

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Selection

The following selection criteria should be considered:

- Gauge should be local to the study catchment
- Length of record available
- Periods of missing data
- Format of the data

Length of record

The record length should be between 20 and 30 years to obtain an accurate representation of the local site conditions.

Format of data

STORMPAC has the capability to input daily data in various formats. These are .**XLS**, **.DAT** and .**SCF** files. The current format supplied by the Met. Office is an MS Excel, .**XLS**, format.

The XLS worksheet has three columns for the date/time information (Day, Month, Year or sometimes Year, Month, Day) and a fourth for the daily rainfall value. An example of the correct format is supplied with STORMPAC as Daily.xls. On some occasions a quality code may also be supplied in an extra column to the right of the rainfall value. This code represents the quality of the rainfall value recorded. A key for the code values is usually supplied at the end of the rainfall data. These quality data are not used by STORMPAC. It should be noted the header information on the rainfall files and the different available formats do not present a problem to STORMPAC with respect to successfully reading in the daily rainfall data.

Another file format that STORMPAC can import that has been used by the Met. Office for daily rainfall data has the extension .DAT. The first line of data shows a reference number of the site, the year and then 12 monthly totals of rainfall. Line 2, (starting with 1) shows the daily rainfall totals (in mm) for January; line 3, (starting with 2) daily totals for February etc. Line 14 starts with the reference number of the site for the next year. An example of this format is shown in Table 5.5.

The format of files with the extension .SCF has already been described in Section 5.1.5.3 with respect to hourly data. However, this format may also be used to represent daily time series, as the STORMPAC daily import routine also has the facility to read this file type. An example of the .SCF file format is shown in Table 5.2.

STORMPAC stores the imported data in the Daily table of the current project database. The format, as with the Hourly table are simply two fields: date/time information and corresponding rainfall depth data (in mm).

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No blanks

STORMPAC requires that all fields of each row and column have integer values. Therefore, **do not leave blank fields**. A message box will be displayed if the daily time series is not continuous.

Table 5.4 Example of the Daily Rainfall Data Format Supplied by the Met. Office

99999123456	1961	906	723	382	524	385	201	846	991	536	1279
1	99999	10	196	0	165	0	46	8	58	0	71	18
2	0	0	53	0	94	84	3	89	25	0	76	38
3	18	0	0	0	0	0	0	0	3	0	56	10
4	28	0	0	61	130	20	0	20	15	5	56	48
5	58	25	15	41	0	38	79	36	5	0	0	0
6	0	5	0	0	10	0	23	0	20	51	0	0
7	0	0	97	0	0	0	23	0	0	5	46	445
8	0	0	198	5	51	23	114	406	3	56	0	3
9	74	51	0	0	18	46	0	0	8	0	25	61
10	0	51	0	41	0	33	76	23	58	23	20	0
11	38	53	0	20	0	0	74	0	0	0	3	36
12	0	0	36	208	25	0	0	76	102	51	102	76
99999123456	1962	1718	547	319	658	483	304	736	1252	1276	387	
1	0	0	0	0	79	36	0	274	5	226	124	48
2	0	0	18	51	36	33	15	0	3	5	269	8
3	25	0	0	18	0	0	0	36	36	3	0	0
4	43	130	79	36	8	84	10	97	25	33	3	0
5	0	0	0	0	10	0	8	0	0	66	74	0
6	0	0	0	0	0	0	0	0	0	0	23	10
7	0	0	0	0	0	0	0	0	0	213	0	0
8	0	69	312	0	5	3	18	0	10	112	10	0
9	28	51	0	86	38	0	38	38	173	41	290	0
10	51	0	0	3	0	0	0	0	0	0	0	0
11	41	48	8	3	23	10	20	5	10	3	0	0
12	0	0	0	0	0	0	196	51	25	23	33	15

Key: Line 1: Site reference number, year and 12 monthly rainfall totals in mm (Jan, Feb, …)

Line 2: January daily totals (mm)

Line 3: February daily totals (mm)

…… until next year

Line 14: Next year header information – site reference, etc.

Missing/Trace/29 Feb data

Missing data points represented by –999, -99999 or 99999 (Met. Office standard formats) will be replaced with zeros. However, any other representation of missing data will be read directly. Therefore, the user is advised to check the validity of a daily time series before attempting to import into STORMPAC. In addition, rainfall falling on 29 February will be retained in the data time series and used in the SRG calculations.

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5.2.4 Average Annual Rainfall

Need

The Annually Regionalised version of the SRG requires an average annual rainfall value.

Source

Standard average annual rainfall (SAAR) data can be obtained directly from the Met. Office, from annual published books by the Met. Office, from the Wallingford Procedure, Volume 3[4] or from the Flood Estimation Handbook[17].

5.3 SMD Data

5.3.1 Need

SMD data are needed to calculate UCWI values.

5.3.2 Source

SMD data are available for many sites throughout the UK and may be obtained from the Met. Office.

5.3.3 Selection

Selection of the most appropriate SMD data should be carried out in consultation with the Met. Office. A representative soil type and land use value for the study catchment should be considered in selecting the data.

5.3.4 Length of record – historical

SMD data are required in either a long term end of month average for each month of the year or a long time series of daily values if historical hourly rainfall data are to be processed and UCWI values calculated. The latter is used by STORMPAC to create long term end of day averages for each day of the year. The Met. Office can supply long term end of month average SMD values.

5.3.5 Format of data – historical

The Met. Office supply SMD data in tabular form usually as an MS Excel worksheet. STORMPAC requires monthly data to be in the form of a series of 12 rows (one for each month). An example file, SMD.XLS, is saved on your computer when STORMPAC is installed. Each row contains the month in column 1 and the long term average SMD value in column 2. STORMPAC will ignore the header information if present at the top of the worksheet. The format of daily SMD time series is the same as that for daily rainfall data. A full description of this is given in Section 5.2.3. **Note: the SMD data file should have the file extension .XLS**.

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5.3.6 Simulated records

Simulated SMD data are calculated from the imported rainfall data (either daily or hourly) or the simulated SRG hourly data. Long term end of day averages for these calculated data are plotted against the imported SMD data. The goodness of fit between the two SMD distributions is also displayed. Parameters used in the calculations can be adjusted and a new distribution is generated if the user is not satisfied with the calculated distribution.

5.3.7 Format of data – simulated

Simulated SMD values for the calculation of UCWI values for simulated rainfall are held within STORMPAC during a project run. However, they are not saved within the project database.

5.4 The Event File

5.4.1 Need

An event file has several applications. It holds summary information of all events from the considered rainfall series as defined by the user's specifications. Events are specified in terms of an inter-event dry period selected by the user. Further filtering in terms of event total rainfall depth, maximum intensity and mean intensity can also be performed. Events are displayed in tabular form by STORMPAC. This enables the user to view the results of their event specification and decide if further modifications are necessary before event data are exported for use in other applications, such as HydroWorks. In addition to filtering, STORMPAC has the facility to sort data by any of the variables displayed in the Events table in either ascending or descending order and also, if required, exclude data that lies outside the typical bathing season (May to September inclusive).

The Events form can be closed once the user is satisfied with the events defined and filtered from the data. STORMPAC automatically copies the event information to a CSV file (comma separated variables) when the user exits from the Events form. The name of this events file is specified by the user on the Events form. It should be noted that the Events table in the project database contains **all** events as defined by the inter-event dry period and ignores any filtering performed by the user – hence, this would have to be repeated if the project is reopened.

The filtered events also act to define which locations to extract data from the disaggregated time series when writing export files. The layout of the Events form is shown in Figure 5.3.

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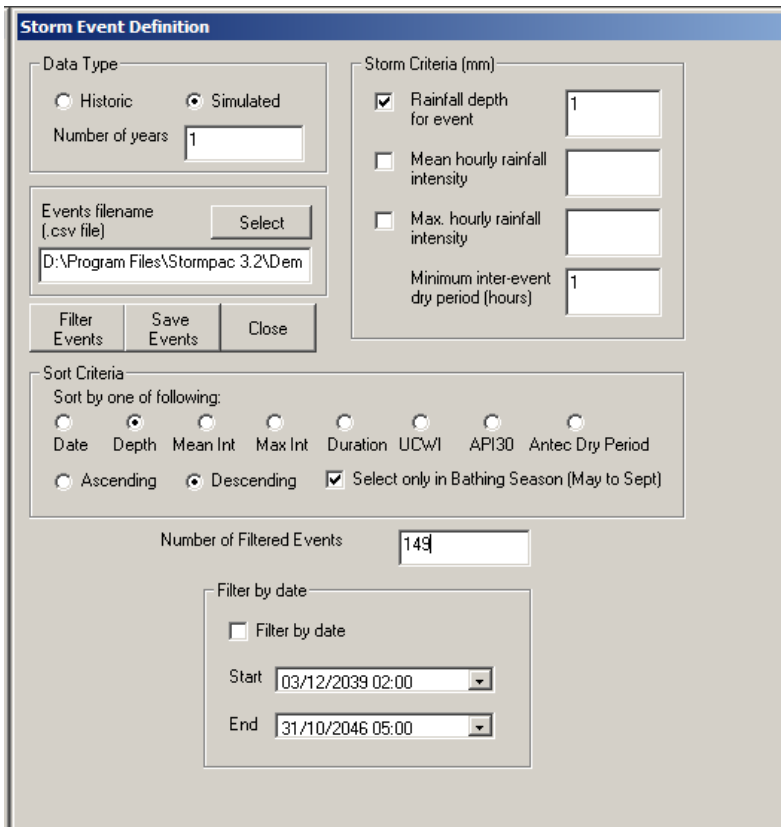

Figure 5-3 STORMPAC Form Used to Define Storm Events

5.4.2 Source

Initially, STORMPAC processes hourly rainfall into an event file ordered chronologically. As described above, these data can then be sorted by any of the variables included in the events summary. Other sources of rainfall can also be imported to the package and processed at this stage, once converted into the correct format.

5.4.3 Length of record

The maximum length of record that can be processed in STORMPAC is 100 years.

5.4.4 Length of storm

There is no maximum length of storm event that can be produced by STORMPAC.

5.4.5 Format of data

Each record in the Events table in the project database represents a storm event. The columns are defined as shown in Table 5.6.

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Table 5.5 Column Headings Used in the Events Table of the Project Database

Column Number	Variable
1	Start Date/Time
2	End Date/Time
3	Depth (mm)
4	Mean Intensity (mm/hour)
5	Maximum Intensity (mm/hour)
6	Duration (hours)
7	UCWI (mm)
8	API30 (mm)
9	Antecedent Dry Period (hours)

5.5 The WASSP PCD File

5.5.1 Need

WASSP PCD files can be used directly with WASSP. The data contained within them are disaggregated rainfall. STORMPAC has the facility to import .PCD files populating the Disaggregation table in the project database. The five minute values are also summed to obtain hourly rainfall data to populate the Hourly table in the project database. This facility enables STORMPAC to reanalyse disaggregated data and redefine storm events. The hourly time series obtained from this import routine has to assume zero rainfall for all times outside the events described in the .PCD file. This is necessary to ensure that a continuous time series of rainfall is generated. However, the user should be aware that this may not be as good a representation for a region as would be obtained from reanalysing the initial historical hourly or daily rainfall data.

5.5.2 Format

An example of the WASSP PCD format is shown in Table 5.7. The first three lines in the file contain the header information about the site where the data originates. Each event is then described separately. For each event, the first 3 rows represent summary information about the storm. The disaggregated rainfall data are then displayed in rows of 10 equally spaced data entries. The PCD file must be in *chronological* order.

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Table 5.6 WASSP Data Format

```
WRc WASSP Data. Date: 12-16-99  Time: 13:34:09  Storm  Location: leixlip
Total Number of Events: 300  300 highest depth storms from
20 year SRG at Leixlip Ireland
  **  1 ** EVENT 1      23:00      2/1/0       96 VALUES   UCWI=126
      0.30       126          1
   96  300  720  600
   0.512   0.512   0.000   0.000   0.288   0.288   0.288   0.000   0.000   0.000
   0.000   0.000   0.288   0.864   1.728   1.440   1.152   1.728   2.016   2.304
   2.528   2.816   3.680   2.016   2.304   0.864   1.152   0.288   1.152   0.864
   2.592   2.592   3.456   2.304   3.392   4.256   5.408   5.184   4.896   4.896
   7.008   8.448   8.448   7.776   6.624   6.048   4.032   3.456   2.592   3.440
   4.016   4.880   2.880   1.440   0.864   1.152   2.304   2.016   1.728   0.864
   1.152   2.592   2.304   2.304   1.728   2.016   2.016   2.016   2.304   2.464
   2.464   2.352   2.480   2.192   2.304   1.440   1.152   1.728   2.016   2.016
   0.864   1.440   1.440   1.440   1.152   2.304   2.304   2.320   1.744   1.744
   1.152   0.864   0.864   0.864   0.288   0.000
  **  2 ** EVENT 2      20:00      5/1/0       84 VALUES   UCWI=151
      0.30       151          1
   84  300  630  600
   0.000   0.000   0.000   0.512   0.512   0.800   0.288   0.288   0.000   0.000
   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.400   0.400   0.400
   0.000   0.000   0.000   0.000   0.000   0.288   0.288   0.288   0.000   0.000
   0.288   1.360   1.360   1.648   1.152   1.728   2.016   1.440   0.864   0.576
   1.440   1.440   1.856   1.280   1.568   0.864   1.440   1.440   2.016   1.152
   1.152   0.576   0.864   0.864   0.864   1.456   1.744   1.744   1.728   1.728
   1.440   0.864   1.056   1.632   2.208   1.728   1.440   1.152   1.152   0.864
   0.576   0.288   0.800   0.512   0.512   0.000   0.000   0.288   0.288   0.288
   0.000   0.000   0.000   0.000
```


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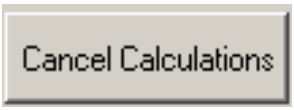
6. DESCRIPTION OF MAIN FORMS AND BUTTONS

6.1 General

The exit button on most forms allows you to unload the form from memory.



The cancel calculations button on most forms allows you to stop the current calculation.

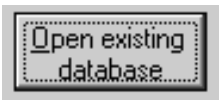
6.2 Parent Window

Once you have loaded STORMPAC 4.1, click this button to run the program. Alternatively click the splash screen. This will display the Control Interface form.

Click the *Stop* button to terminate the program and unload it from memory.

Click the question mark button to display the HTML help system.

Click the *Create database* button to create a new STORMPAC 4.1 database and save it by selecting a directory and entering a filename in the Save As dialog box.



Click this button to open an existing STORMPAC 4.1 database. Browse through directories until you select the correct one. On opening a database, a message box will appear reminding the user of what tables have been created in the database.

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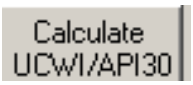
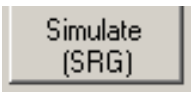
You must click this button at some point during the STORMPAC run, even if you open an existing database that already contains site information data. By clicking the button, the site information form is displayed. You must fill in the relevant information, making sure to select the correct data type (Hourly, Daily, Annually). Different statistics are calculated for each data type. Also, remember to change the record duration for the simulated data. The default is 20 but you may wish to put in a different value (see Section 6.3).

Click one of these buttons to import rainfall data. The format and time step of your rainfall data should determine which button to click. Section 5 describes all the different formats. By clicking this button a progress bar is displayed which shows the progress of the rainfall import. A message box appears at the end of the import specifying whether the import was successful or not. Click *OK* to continue.

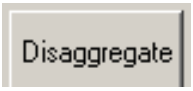


Click this button to display the SMD calculations form. (See Sections 6.4 and 6.5)



Click this button to display the parameter fitting interface form. (See Section 6.6)

Click this button to display the storm event definition form. (See Section 6.7)



Click this button to display the hourly rain disaggregator form. (See Section 6.8)

Click this button to display the file export form. (See Section 6.9)

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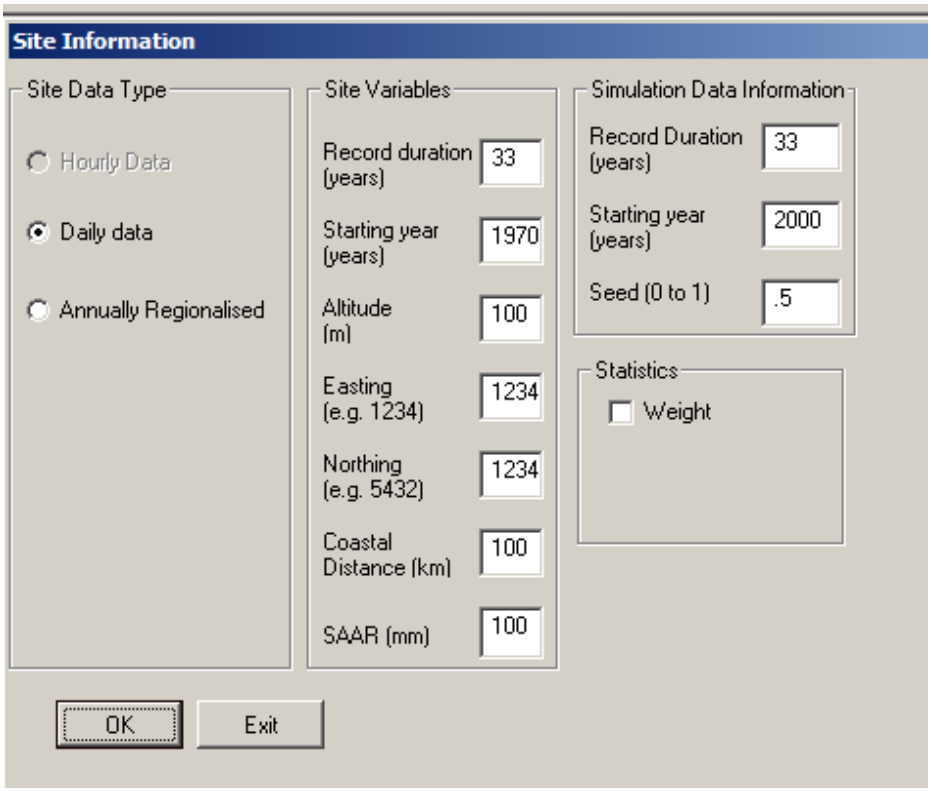
6.3 Site Information Form



By clicking *OK* on this form, statistics are calculated depending upon the data type you specified on the form. Checks are also made on all the site information variables to see if they are numeric or within the allowable ranges specified in the program (see Table 5.4). If your site is outside these ranges, you can still generate rainfall, but a process of extrapolation takes place and the program warns you of this.

6.4 SRG – Parameter Fitting Interface Form

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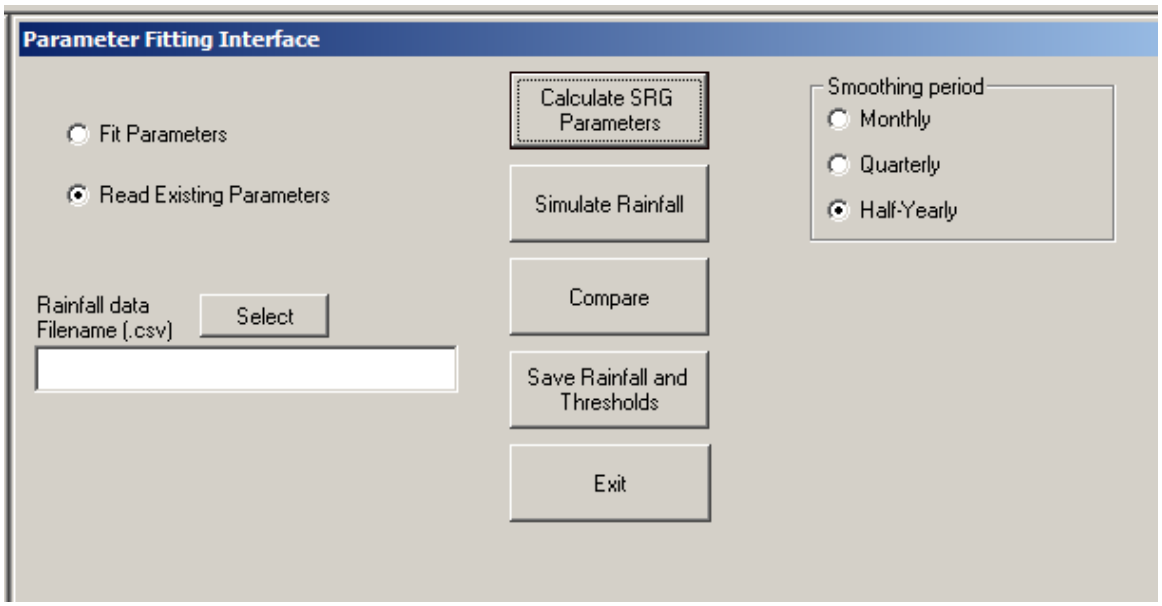

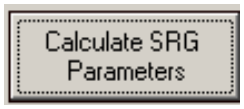

You must click the *Calculate SRG Parameters* button to fit the model parameters to the rainfall statistics calculated when you clicked *OK* on the site information form, this process may take a long time. Ensure that the Fit parameters option is selected. When these parameters have been generated they will appear in a table at the bottom of the screen. See Appendix A for examples.

If your database contains existing parameters, or if you have just fitted them to your sample rainfall statistics (the parameters are produced after clicking the *Calculate SRG Parameters* button), click the *Simulate Rainfall* button to generate 'x' number of years of SRG rainfall data. This is saved to the SRGData table in the STORMPAC 4.1 database. 'x' is the Record Duration (years) specified on the site information form. When rainfall has been simulated three graphs will appear on the right hand side of the screen. These show a comparison of the simulated data and any historical daily data which has been imported, in the form of a time series, a cumulative frequency graph and a quantile plot, which shows rainfall at points of equal probability of occurence. These charts can be viewed in more detail and exported by clicking on the *Graphical Views* button.

To export the simulated rainfall click the *Select* button to choose a directory and filename for the CSV files.

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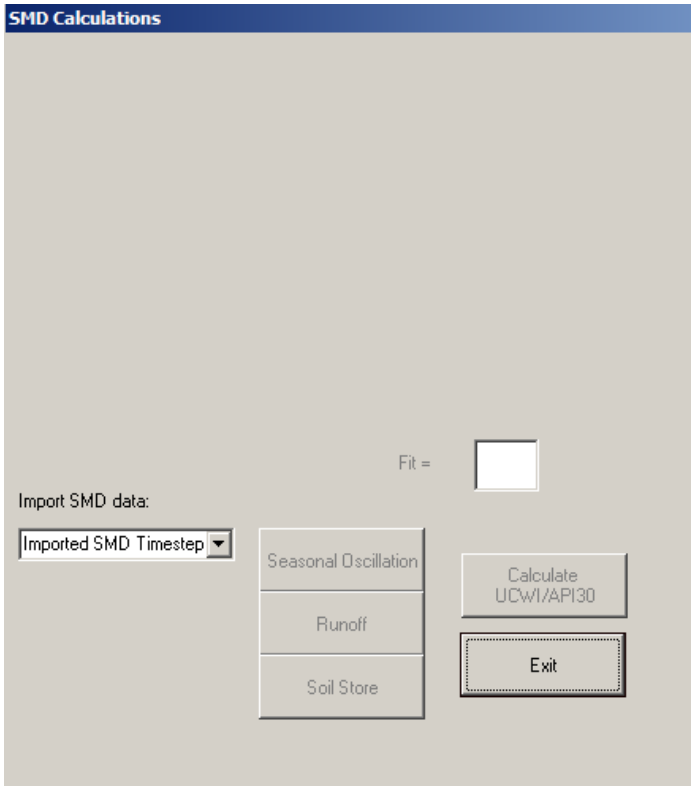
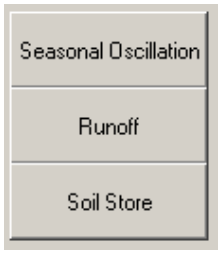
The *Save Rainfall and Thresholds* button allows you to save your generated rainfall to a CSV file. The output file contains hourly generated rainfall totals with a date/time stamp. One row is equal to one hour. A second file will be generated with the suffix '_Threshold' in its filename. This file records a summary of daily threshold totals of the generated rainfall. A summary of historic hourly rainfall will also be recorded if you have loaded hourly rainfall in your STORMPAC database.

6.5 SMD Form



Select the imported SMD time step from the drop down box and then browse to the location of the SMD file and choose Open. A message box appears informing the user whether the import was successful or not. After import, a plot of calculated and imported SMD values is displayed on the top of the SMD form. Click on the chart labels to change the colours if required.



Click these buttons to display the seasonal oscillation, runoff or soil store forms. Each of these forms contains parameters pertaining to the SMD model. By selecting different parameters you can calibrate the model to fit the imported SMD data.

Change the colours on the SMD graph by clicking on the chart labels.

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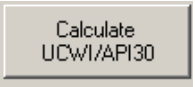
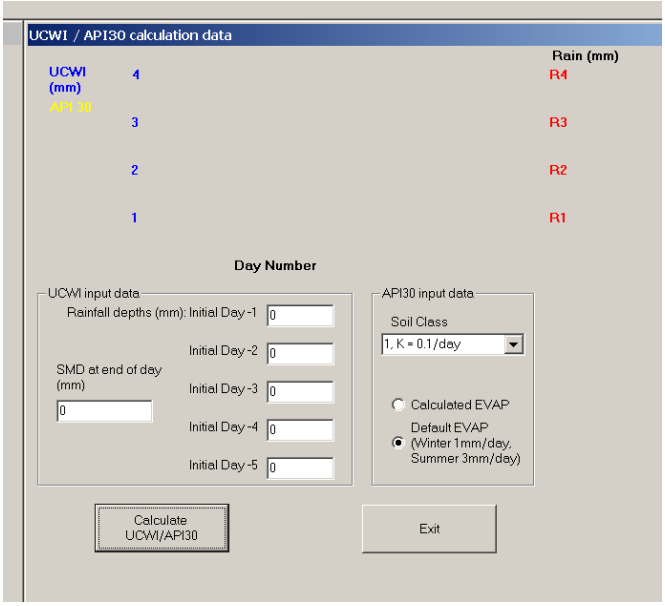
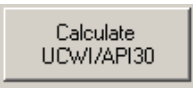


Click this button to display the UCWI/API30 calculation form. (See Section 6.5). You should only click this button if you have achieved a good SMD calibration, i.e. goodness of fit greater than 0.9.

6.6 UCWI /API30 Calculation Form





Click this button after you have filled in the necessary information on the UCWI form (see Section 4.7 and Figure 4.13). Then the program calculates UCWIs and plots rainfall depth and UCWI values. This plot is a visual aid to allow the user to determine if the first few days of UCWI calculations are acceptable. For example, that they contain no negative values.

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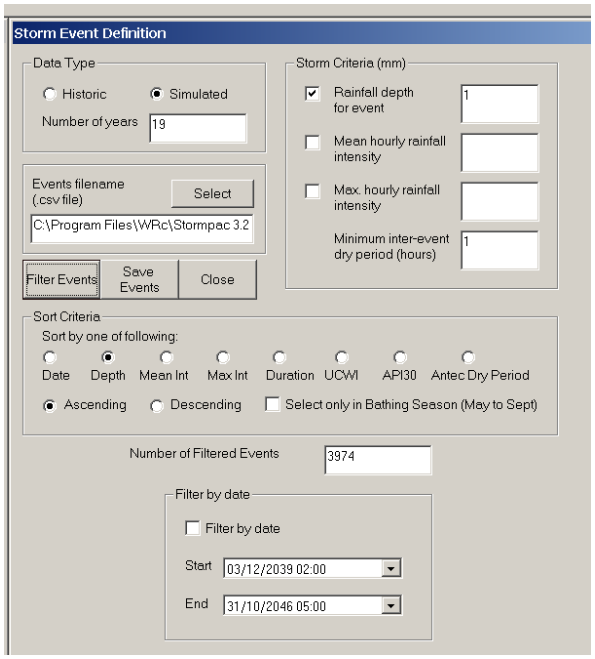
6.7 Storm Event Definition Form



Select criteria to sort storms. Check the Filter by date button to filter down to a smaller time-period using the calendar boxes to enter a start and end date. This allows the user to filter down to one rainfall event. This may be useful if a 'typical year' of rainfall events has already been selected. The events selected here will be available to output in the File Export form.

By clicking this button you will generate an events database that has the storm identification and sort criteria specified on the storm event definition form. Another window appears on top of the control interface form allowing the user to view the data.

If you click this button the filtered events will be saved to a CSV file. You must specify a file name in the events filename box on this form to which the filtered data will be saved. Note you can filter the data as much as you require, but the events database will not be over written. You must change the minimum inter event dry period value, which is the underlying value defining an event to overwrite the events database.

Click the *Close* button to close this form.

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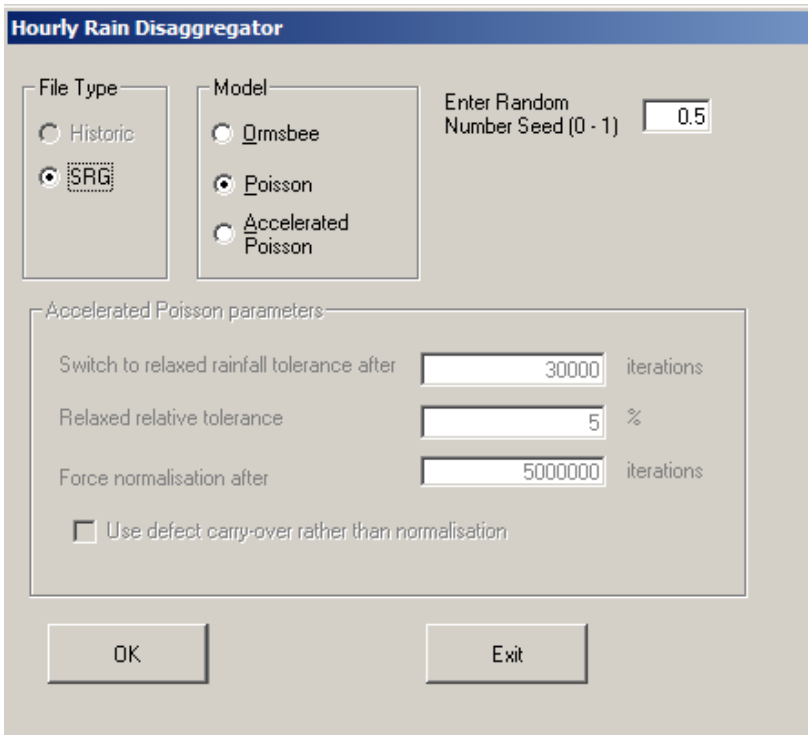
6.8 Hourly Rain Disaggregator Form



Choose the appropriate data type: Historical or SRG (Simulated). Then make sure the Poisson is selected. If this process takes too long (several hours) select the accelerated Poisson disaggregator and alter the parameters as required.

For example the 'Switch to relaxed rainfall tolerance after 30,000 iterations' or 'Force normalisation after 5,000,000 iterations' can be reduced to speed up the process. See section 2.3.3 for details.

Click OK to start the disaggregation calculations. The process may take some time if there is a long time series to disaggregate. The data are then written to the Disaggregator table in the STORMPAC database.

Note: Zeros are excluded from the Disagg table but will be put back into the disaggregated data when export files are created.

6.9 File Export Form

The picture below shows the export form as it would look if HydroWorks was selected as the export file type. There is the option to include UCWI and API30 values on the profiles and change local arial reduction factor. The Export Multi-event file option will produce a RED file with all selected events. The Export Single Event Files option will produce a file for each event.

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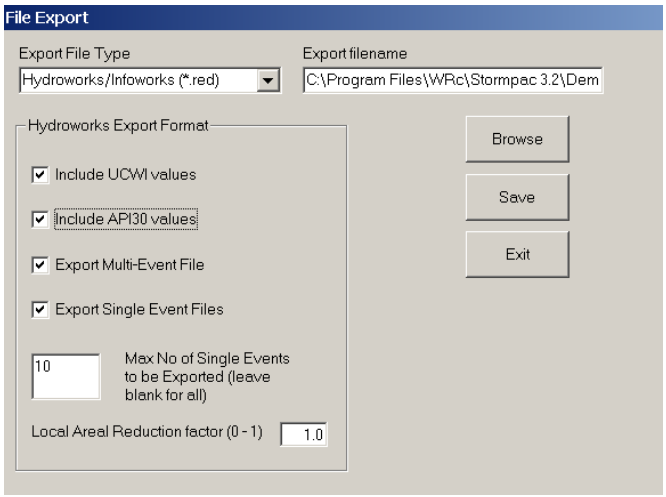

Clicking the *Browse* button allows you to choose where to save the exported files to and a file name.

Clicking the *Save* button saves the data in the chosen format. Files are written to the chosen directory. In the Max No of Single Events to be Exported box fill in the number of files that you want to produce. If this box is left blank all events will be exported as files, this may number 1000 files or greater.

6.10 Data views form

This form has the same functionality as the charts and tables shown after the SRG simulation. Summary statistics are generated from the imported daily data 'Daily' table and hourly stochastic rainfall 'SRGData' table. These are presented either as monthly or threshold analysis and can be used to compare the generated hourly data with imported historical daily data.

Selecting threshold analysis gives the average number of days above any given threshold in a single bathing season. Monthly average rainfall shows the average monthly SRG rainfall from the SRGData table compared to the average monthly rainfall in the Daily table. If both SRG and Daily (historic) data are available, both are shown, so that a comparison can be made.

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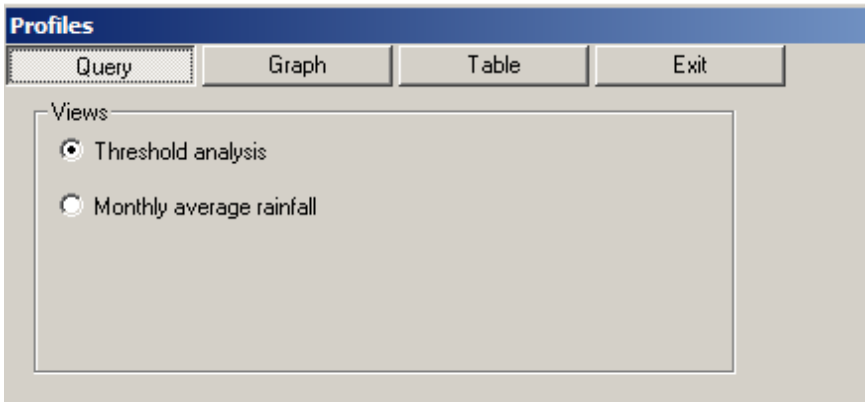
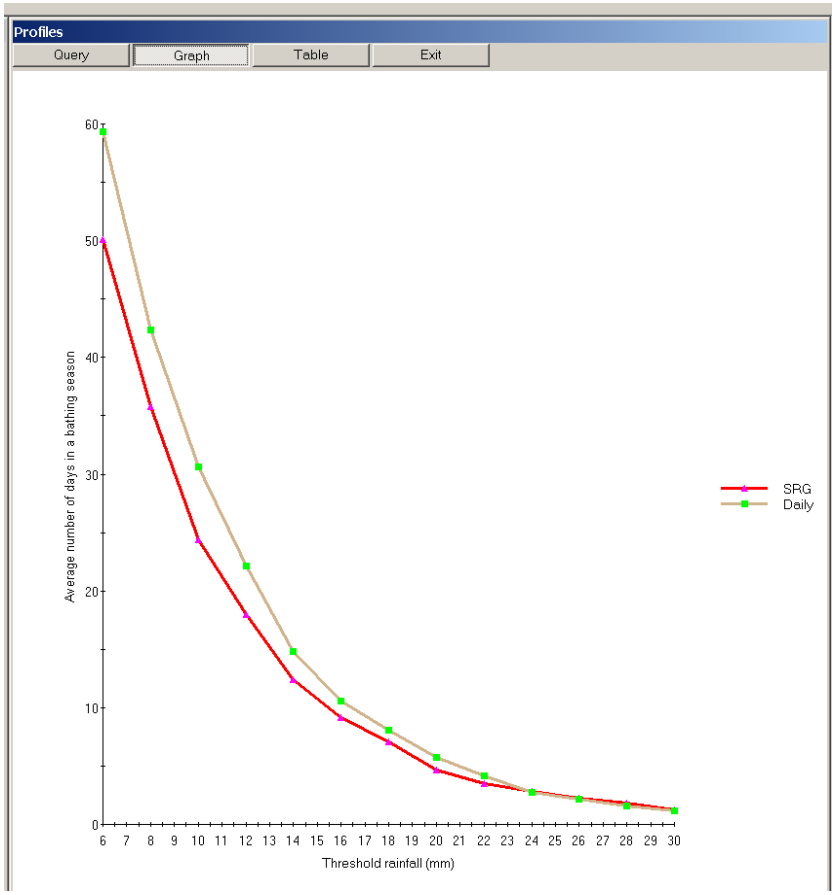


Clicking the *Graph* button allows you to view these results as a graph.



Clicking the *Table* button shows them as a table of data. This data can be copied to MS Excel.

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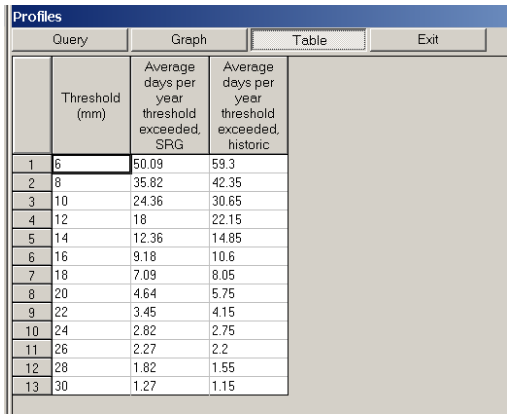
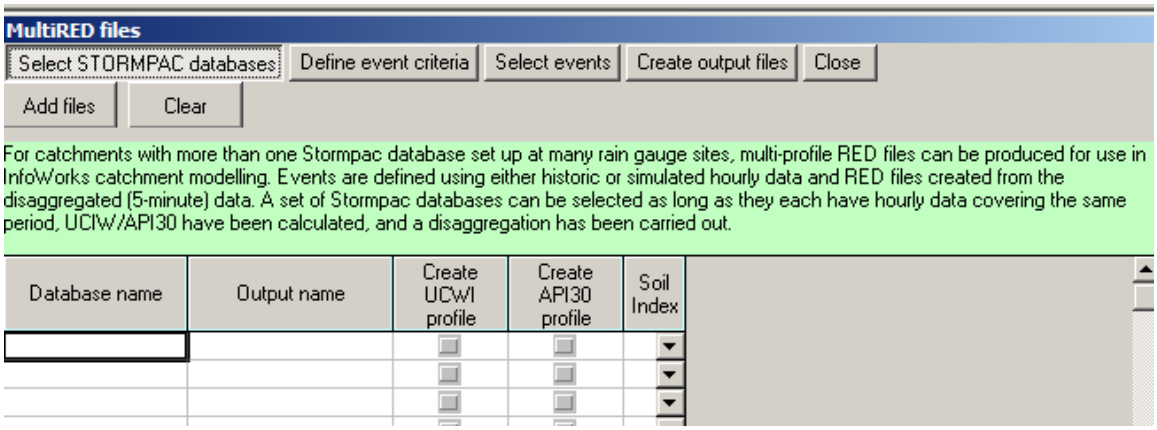


	Threshold (mm)	Average days per year threshold exceeded, SRG	Average days per year threshold exceeded, historic
1	6	50.09	59.3
2	8	35.82	42.35
3	10	24.36	30.65
4	12	18	22.15
5	14	12.36	14.85
6	16	9.18	10.6
7	18	7.09	8.05
8	20	4.64	5.75
9	22	3.45	4.15
10	24	2.82	2.75
11	26	2.27	2.2
12	28	1.82	1.55
13	30	1.27	1.15

6.11 Multi-RED analysis

This requires selection of one or more Stormpac databases with data covering the same time period and either all stored in the Hourly tables or all stored in the SRGData tables. Use *Add files* to add databases – multiple databases can be selected if they are all in the same location. Use *Clear* to remove all entries. The form can be populated and edited directly or by copying data to MS Excel to make changes and then paste back to the form. Take care to paste back the header line as well.


MultiRED files
Select STORMPAC databases
Define event criteria
Select events
Create output files
Close
Add files
Clear
For catchments with more than one Stormpac database set up at many rain gauge sites, multi-profile RED files can be produced for use in InfoWorks catchment modelling. Events are defined using either historic or simulated hourly data and RED files created from the disaggregated (5-minute) data. A set of Stormpac databases can be selected as long as they each have hourly data covering the same period, UCIW/API30 have been calculated, and a disaggregation has been carried out.
Database name
Output name
Create UCWI profile
Create API30 profile
Soil Index

If a chosen database has no SRG data and no hourly data – or, of course, is not a Stormpac database – then it will not be added to the list.

Each database added will automatically default to creating an UCWI and an API30 profile. The soil index value will be set to the value stored within the Stormpac file. The user should confirm that the soil index shown is the value used to calculate the API30 data they have already generated.

A default short name will be taken from the *file name*.

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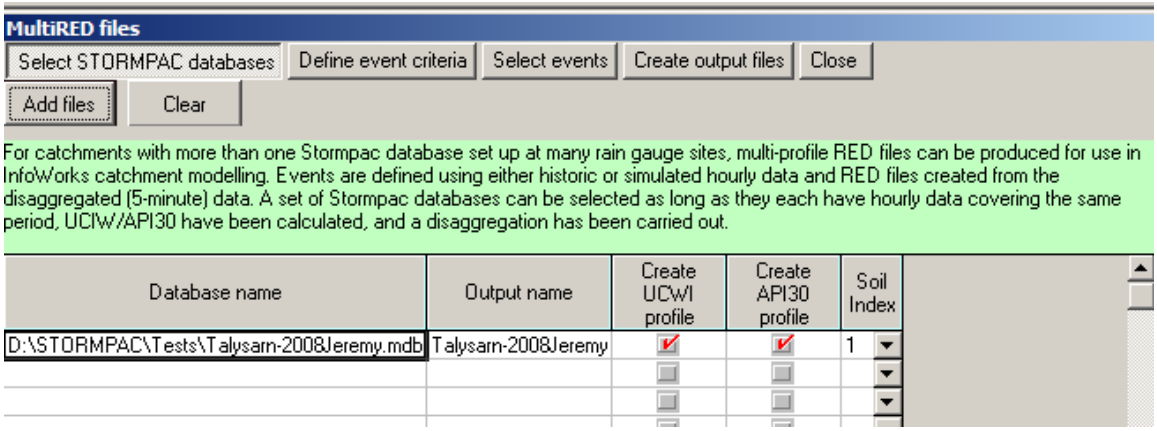
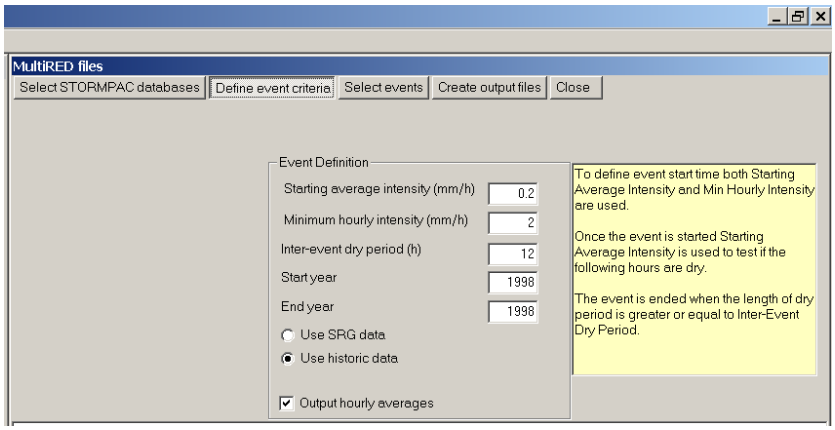

MultiRED files
Select STORMPAC databases
Define event criteria
Select events
Create output files
Close
Add files
Clear
For catchments with more than one Stormpac database set up at many rain gauge sites, multi-profile RED files can be produced for use in InfoWorks catchment modelling. Events are defined using either historic or simulated hourly data and RED files created from the disaggregated (5-minute) data. A set of Stormpac databases can be selected as long as they each have hourly data covering the same period, UCIW/API30 have been calculated, and a disaggregation has been carried out.
Database name
Output name
Create UCWI profile
Create API30 profile
Soil Index
D:\STORMPAC\Tests\Talysarn-2008Jeremy.mdb
Talysarn-2008Jeremy
1

SELECTING EVENT CRITERIA

Having specified all the Stormpac files to be used in analysing for rainfall events, you then move on to specifying what will constitute an event. All the Stormpac files *must* have the same start year and duration for the rainfall events; otherwise, a message to this effect will be produced and you will have to drop or modify the relevant Stormpac databases.


MultiRED files
Select STORMPAC databases
Define event criteria
Select events
Create output files
Close
Event Definition
Starting average intensity (mm/h)
0.2
Minimum hourly intensity (mm/h)
2
Inter-event dry period (h)
12
Start year
1998
End year
1998
Use SRG data
Use historic data
Output hourly averages
To define event start time both Starting Average Intensity and Min Hourly Intensity are used.
Once the event is started Starting Average Intensity is used to test if the following hours are dry.
The event is ended when the length of dry period is greater or equal to Inter-Event Dry Period.

Two parameters are used together to indicate that an event has begun. First, the average rainfall intensity across all sites must exceed the specified *starting average intensity (mm/hour)* and secondly, the minimum rainfall for at least one site must exceed the specified *miniumum hourly intensity (mm/hr)*. Once an event has started the *starting average intensity (mm/ hour)* value is used to test if the following hours are dry. The event is ended when the length of the dry period is greater than or equal to the specified *Inter-event dry period (hours)*.

In addition, the events can be created using either SRG or hourly data. If there is no data for your chosen option of SRG or hourly you will be informed that you should change the choice.

SELECTING EVENTS

Proceeding to select events, there will be a pause while the events are being identified. Following identification the events will be displayed on two grids.

The default is for all events to be selected, but any event can be excluded if required. The screen displays two grids. The upper grid displays summary parameters for the event, and allows you to include or exclude events by clicking on the *Include event* tick box (far right hand column).

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Events can be sorted to help select a set of events to export as RED files or changing the export order by clicking on column headers to cycle between sort ascending and sort descending.

To reduce the number of events that will be exported as RED files, select a block of rows, then click on the *Include event* tick box (far right hand column), to select/deselect a block of events. Note - if you select a mixture of selected and deselected rows, they will toggle, rather than all select/deselect.

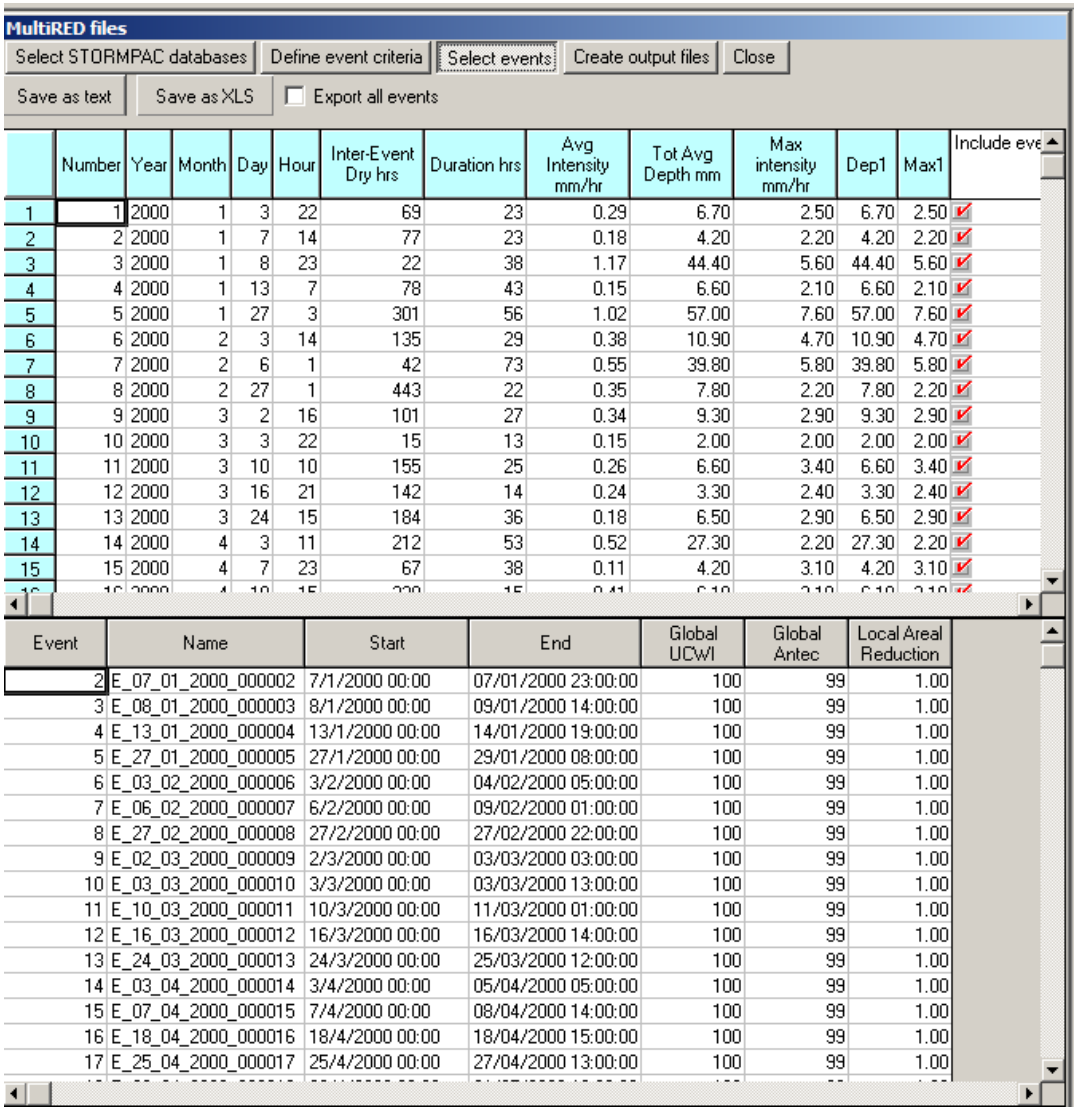
The lower grid displays the chosen events, and allows you to change the following:

1 Event name.

2 Default UCWI to be used if the individual Stormpac files not have UCWI values.

3 Default API30 values to be used if the individual Stormpac files not have API30 values.

4 Default Antec values if the individual Stormpac files do not have Antec values.



	Number	Year	Month	Day	Hour	Inter-Event Dry hrs	Duration hrs	Avg Intensity mm/hr	Tot Avg Depth mm	Max intensity mm/hr	Dep1	Max1	Include eve
1	1	2000	1	3	22	69	23	0.29	6.70	2.50	6.70	2.50	☑
2	2	2000	1	7	14	77	23	0.18	4.20	2.20	4.20	2.20	☑
3	3	2000	1	8	23	22	38	1.17	44.40	5.60	44.40	5.60	☑
4	4	2000	1	13	7	78	43	0.15	6.60	2.10	6.60	2.10	☑
5	5	2000	1	27	3	301	56	1.02	57.00	7.60	57.00	7.60	☑
6	6	2000	2	3	14	135	29	0.38	10.90	4.70	10.90	4.70	☑
7	7	2000	2	6	1	42	73	0.55	39.80	5.80	39.80	5.80	☑
8	8	2000	2	27	1	443	22	0.35	7.80	2.20	7.80	2.20	☑
9	9	2000	3	2	16	101	27	0.34	9.30	2.90	9.30	2.90	☑
10	10	2000	3	3	22	15	13	0.15	2.00	2.00	2.00	2.00	☑
11	11	2000	3	10	10	155	25	0.26	6.60	3.40	6.60	3.40	☑
12	12	2000	3	16	21	142	14	0.24	3.30	2.40	3.30	2.40	☑
13	13	2000	3	24	15	184	36	0.18	6.50	2.90	6.50	2.90	☑
14	14	2000	4	3	11	212	53	0.52	27.30	2.20	27.30	2.20	☑
15	15	2000	4	7	23	67	38	0.11	4.20	3.10	4.20	3.10	☑

Event	Name	Start	End	Global UCWI	Global Antec	Local Areal Reduction
2	E_07_01_2000_000002	7/1/2000 00:00	07/01/2000 23:00:00	100	99	1.00
3	E_08_01_2000_000003	8/1/2000 00:00	09/01/2000 14:00:00	100	99	1.00
4	E_13_01_2000_000004	13/1/2000 00:00	14/01/2000 19:00:00	100	99	1.00
5	E_27_01_2000_000005	27/1/2000 00:00	29/01/2000 08:00:00	100	99	1.00
6	E_03_02_2000_000006	3/2/2000 00:00	04/02/2000 05:00:00	100	99	1.00
7	E_06_02_2000_000007	6/2/2000 00:00	09/02/2000 01:00:00	100	99	1.00
8	E_27_02_2000_000008	27/2/2000 00:00	27/02/2000 22:00:00	100	99	1.00
9	E_02_03_2000_000009	2/3/2000 00:00	03/03/2000 03:00:00	100	99	1.00
10	E_03_03_2000_000010	3/3/2000 00:00	03/03/2000 13:00:00	100	99	1.00
11	E_10_03_2000_000011	10/3/2000 00:00	11/03/2000 01:00:00	100	99	1.00
12	E_16_03_2000_000012	16/3/2000 00:00	16/03/2000 14:00:00	100	99	1.00
13	E_24_03_2000_000013	24/3/2000 00:00	25/03/2000 12:00:00	100	99	1.00
14	E_03_04_2000_000014	3/4/2000 00:00	05/04/2000 05:00:00	100	99	1.00
15	E_07_04_2000_000015	7/4/2000 00:00	08/04/2000 14:00:00	100	99	1.00
16	E_18_04_2000_000016	18/4/2000 00:00	18/04/2000 15:00:00	100	99	1.00
17	E_25_04_2000_000017	25/4/2000 00:00	27/04/2000 13:00:00	100	99	1.00

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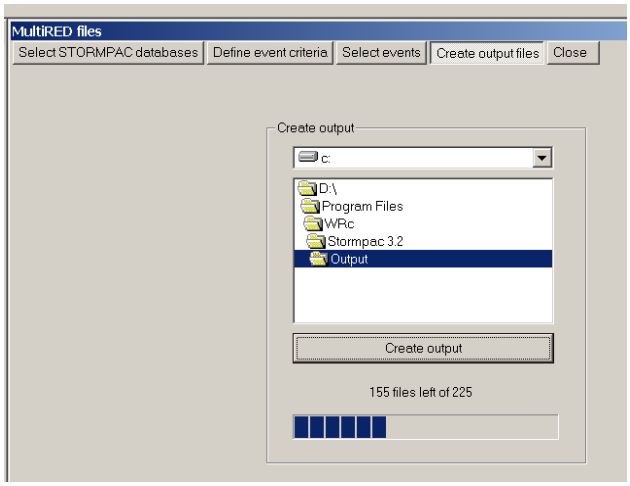
PRODUCING OUTPUT

Finally, a location can be selected for where the output files are to be created. Note that the selected folder will have an *open* folder displayed; if the folder is displayed as *closed*, you will need to click on it again to select it.



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7. SMD MODEL

A sinusoidal model (radians) approximating the magnitude of potential evaporation over one year is given by the following equation,

$$PE = F\left[\sin\left(\frac{2\pi(t-x)}{365} - \frac{\pi}{2}\right) + 1\right] - A$$

where F is the seasonal amplitude factor (typical values 0.1 to 10)

x is the seasonal offset factor (days) (typical values – 30 to 30)

A is the amplitude shift factor (typical values -1 to 5)

PE is Potential Evaporation, any negative PE values are set to zero

t is the day number from 1 (1st January) to 365 (31st December)

F determines the amplitude of the shifted sinusoid function, which has values between 0 and $2F$. For example with A and x set to zero and F set to 1 the peak will occur half way through the year with a value of 2 (which is equivalent to 2 mm).

A shifts the value of PE (mm) up (negative A) or down (positive A) the y-axis by the corresponding amount.

x shifts the values left (negative x) or right (positive x) on the time axis by the corresponding number of days.

Runoff is calculated and a simple water balance is carried out for each hour (i) of the rainfall in the historical hourly or SRG hourly database to determine the volume of water stored at the end of the day using the following calculations:

Runoff (i) = MAX*(Rain (i) - Rthres,0)*Rfactor* *if Runoff (i) > Rain (i) then*

Runoff (i) = Rain (i)

where *Rthres* is the Rainfall Threshold (mm)

Rfactor is the Runoff Factor

Rain (i) is the rainfall depth value (mm) for the current hour

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$Vol1\ (i) = \text{MIN}(Vmax, Vol2\ (i-1) + Rain\ (i) - Runoff(i))$

$Vol2(i) = \text{MAX}(0, Vol1\ (i) - \text{MIN}(1, Vol1\ (i)/Vthres) * PE(i))$

where *Vmax* is the full soil store (mm)

Vol2 (i –1) is the Volume in store 2 in the preceding hour

Rain (i) is the rain depth (mm) in the current hour

Runoff (i) is the Runoff (mm) in the current hour.

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8. FREQUENTLY ASKED QUESTIONS

8.1 Do I need Microsoft Access to run STORMPAC 4.1?

No, STORMPAC 4.1 needs only a reference to the JET Database Engine that is on your machine. The necessary files are copied during installation if they are not already on your computer. You will, however, need MS Access 97 or later if you want to look at the database. If you are running later versions than Access 97, you will be asked if you want to update the database. Reply 'no', as you will not be able to write to the database and you will not be able to run STORMPAC with that database. Useful files are also saved to disk at various stages of STORMPAC giving the user the option to read these using a spreadsheet such as MS Excel or a text editor, such as Wordpad.

8.2 What is the minimum length of daily record I should import?

It is recommended that a minimum of 20 years daily data should be imported. However, weighted averages of the regression estimates and site estimates taken from the site data can be calculated if your historical series is relatively short (say less than 10 years). Remember to select the checkbox on the site information. The 'weight' checkbox is for users who want to combine historical data with the regionalised model. For example, if a user has five years of daily data these could be combined with the regionalised model to give weighted estimates of the statistics needed to fit the Neyman Scott Rectangular pulses (NSRP) model, which underpins the SRG algorithm. This is a half-way house between those who want to fit the model using a good record of daily data and those who have no daily data.

8.3 What should I do if I have no data at my site to compare values?

In these circumstances the normal procedure is to annually regionalise the data based on site variables. However, in mountainous areas or areas where a microclimate is suspected the annually regionalised data may not compare very well with historical data. Of course you have no historical data to compare against. We therefore recommend a sensitivity analysis to be carried out.

8.4 I'm unsure if my SMD calibration is good enough.

STORMPAC 4.1 models the daily end of day SMD based upon a model of the potential evapotranspiration. You must calculate the daily SMD even if you import daily SMD data. When importing daily SMDs, the long term daily averages are calculated and you calibrate the calculated daily SMD values to this curve. To calibrate the model you must fit your calculated SMD to the imported monthly or daily SMD data. A plot of the results is provided as a visual aid along with a fitness factor. A good calibration is assumed if the fitness factor is greater than 0.9. However, you must ensure that the shape of the calculated SMD curve follows the trend of the imported data; for example, low SMD values in winter and a peak value in summer.

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8.5 Should I daily or annually regionalise?

Typically, if you have a sufficient length of daily rainfall data for your site (20 years or more) you should daily regionalise your data. However, it may be wise to annually regionalise the data as well. You can then compare the daily regionalised and annually regionalised rainfall series with the historical series and choose the most appropriate one. Refer to Section 8.3 if you have no site rainfall data to compare to your generated series.

8.6 What return periods is STORMPAC 4.1 valid for?

The software is capable of generating return periods equivalent to those seen in the historical data set. However accuracy of predicted rainfall compared to historical rainfall is better up to a 1 in 20 return period. While the model follows the Gumbel distribution for extreme events beyond a 1 in 20 year return period, observed rainfall events tend not to follow a Gumbel distribution.

8.7 Developments in STORMPAC 3.2 compared to STORMPAC 2.0

STORMPAC 3.0 saw the enhancement of the rainfall generator used in version 2.0. This is more able to generate extreme events that are observed in historical data. Accuracy of the generated rainfall is improved up to 1 in 20 year return period equivalent storms, although the generator is capable of generating storms with higher return periods.

The software was also updated to a more supportable format for users and version 3.1 built on this making the software more user friendly through updates to the interface and allowing users to store and record the parameters and processes used in generating their rainfall and selecting their events.

The latest version has a new built in Poisson rectangular pulses disaggregator. This has been built in as an improvement on the Ormsbee method used in previous versions, and allows five minutely data to be generated more accurately, particularly with more extreme values.

New functions added to the software over this time include:

- Calculation of API30 and as well as UCWI values.
- Greater than 9 hours inter event dry period. Systems with long drain down times can now be studied.
- Continuous disaggregation.
- More than 300 storms can be analysed per run.
- Can be used on more up-to-date operating platforms.
- 50 years rainfall data can be imported.
- Several updates to the user interface.
- All output files can be exported to the directory and folder selected by the user.
- Imported SMD data is now stored within the database.

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- Parameters used in the Soil Moisture Deficit (SMD) calibration and UCWI calculations are now recorded within the database tables and the software will default to these values on reopening of the database.

- Similarly values used to filter and sort events are also recorded within the database, and will be defaulted to on reuse of the database.

8.8 What was new in version 4.0?

- RED file output includes evaporation on the first profile (used in Wallingford runoff model).

- Options added to speed up Poisson disaggregator.

- Chart display to compare summary statistics for imported daily rainfall and generated rainfall.

- Time filter on Event definition form.

- Multi-site RED generator available – this allows the user to generate RED files with many rain profiles.

- Option to change SEED value in SRG removed.

8.9 What is new new in version 4.1?

- Rainfall series of up to 100 years can now be generated

- Calculated SRG parameters and upper and lower parameter limits can be viewed

- Graphical views comparing simulated results with historical data are produced

- Updates to Data Views function

- Create output file function for multi-site RED generation speeded up

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APPENDIX A WORKED EXAMPLES USING STOCHASTIC RAINFALL GENERATOR

Introduction

This Appendix provides a step by step guide on two possible applications of STORMPAC. The methodology follows that shown in the flow diagram given in Appendix B. Section A.3 provides the user with information regarding multiple runs of STORMPAC with different seed values.

A.1 WORKED EXAMPLE 1

Task

Generate 20 years of data (using average annual rainfall published statistics), and produce the largest 50 rainfall events in HydroWorks RED format. The largest events will be found by looking at mean storm intensity values. There is no local hourly, or daily, rainfall information.

Data inputs required

The data inputs required are as follows:

- Average annual rainfall;
- Grid reference for catchment;
- Altitude of catchment;
- Distance from the nearest coast;
- Average SMD values for each month.

The source of these data can be found by looking at Section 5 of the main report.

Setup

Create a new database by clicking the *Create database* button on the Control Interface form. Save the database to a directory.

Site Information

Click the *Site Statistics* button on the Control Interface form to display the Site Information form. Select the *Annually Regionalised* option in the Site Data Type frame then fill in all the blank spaces in the Site Variables frame with the correct site information. Put 20 in the *Record Duration* box and 2000 in the *Starting year* within the Simulation Data Information frame.

Click *OK* to calculate the site statistics and return to the Control Interface form.

SRG Data

To simulate rainfall you must first fit the NSRP model parameters to the sample statistics.

1. Click the *Simulate (SRG)* button to open the Parameter Fitting Interface form.

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2. Select *Fit Parameters*.

3. Click the *Calculate SRG Parameters* button – a progress bar and counter will appear. The optimisation is achieved by the SIMPLEX method (see Press *et al*. [11]).

4. Click the *Simulate Rainfall* button to generate 20 years of rainfall. The rainfall is generated and then written to the SRGData table in your STORMPAC 4.1 database. The number of years generated was specified on the Site Information form.

5. Click the *Select* button and choose a directory and filename for the CSV files.

6. Click the *Save Rainfall and Thresholds* button to create the CSV files.

7. A file of the generated hourly rainfall values is created. Each row in this file has the date and time and a value of hourly rainfall total (mm), the last line in the file has END written in it. Note: if opening this CSV file in MS Excel you may not be able to open the full CSV file because Excel files are limited to 65536 lines of data.

8. A CSV file with the suffix Threshold is created. This file contains frequency analysis results of the number of days when the daily totals, calculated from the hourly SRG data, are above a certain threshold. The thresholds are 10, 12, 14, 16 …..to……40 mm. A monthly summary of rainfall depths is also provided. If you have imported historical daily data the program will also calculate threshold frequency analysis results and monthly depths from the Daily table in the database. This is saved at the end of the Threshold file.

UCWI/API30

Click the *Calculate UCWI/API30* button to display the SMD form. Select *Monthly* from the *Import SMD Timestep* drop down box. Select the relevant monthly SMD file and click *OK* to import the data. Click *OK* on the message box that says “SMD data successfully loaded”. A plot of the imported data (black line) will appear at the top of the form along with a plot of calculated data (red line), derived using default values. Change the colours on the SMD graph by clicking on the chart labels.

Next calibrate the SMD model by changing parameters on the Seasonal Oscillation, Runoff and Soil Store forms (click these buttons to display each of the relevant forms). It is recommended to start with the Seasonal Oscillation form. Change the parameters on the form and click *Apply* to see the changes take effect. Select the *Compare* box to determine what the goodness of fit is. A value greater than 0.9 is sufficient. If a value of 0.9 or greater is not achievable by changing the Seasonal Oscillation parameters (it is recommended to try more than one change of the parameters) then click the *Runoff* button on the SMD form and change the parameters on this form. Again, clicking *Apply* will allow the changes to take effect. Finally, click the *Soil Store* button on the SMD form if you have still not managed to achieve a suitable calibration.

Note a suitable fitness factor is usually achieved after changing the Seasonal Oscillation parameters and the Runoff parameters.

To calculate UCWI and API30 values click the *Calculate UCWI/API30* button on the SMD form.

Select the soil class from the *Soil Class* drop down box and choose the relevant evaporation checkbox. Click *Calculate UCWI/API30* to calculate the values.

Select the *Yes* button in the message box: *“Do you wish to continue?”.*

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Select *OK* in the message box stating that UCWI/API30 calculations are complete, then press the *Exit* button to close the form.

Events

You are now in a position to define some events from your simulated rainfall data. This is achieved by clicking on the *Event Definition* button on the Control Interface form.

1. For the purposes of this exercise put a value of 1 in the *Minimum inter-event period* box to identify all storms in your historical database.

2. Select the *Mean hourly rainfall intensity* option in the Storm Criteria window.

3. Select the *Depth* button in the Sort Criteria window to sort the database by maximum intensity.

4. Select the *Descending* option in the Sort Criteria window, which will sort the database in descending order (i.e. the event with the largest depth will be the first record in the database).

5. Select a directory and choose a file name and directory by clicking the *Select* button. The generated events will be saved to this file.

6. Select the *Simulated* data type option at the top of the form. This ensures that the program will read data from the SRGdata table in the database.

7. Click *Filter Events* and a progress bar and event counter will appear.

8. Click *OK* to the message box: “Events table successfully generated”

9. The events will be displayed on the Control Interface form as they are stored in the database. Click on the *Close* button.

10. Click *Save Events* to save the events as a CSV file.

11. Click *Close* to return to the Control Interface form.

Disaggregation

To disaggregate the data click the *Disaggregate* button on the Control Interface form. This displays the Hourly Rain Disaggregator form.

Select the SRG option to make sure the SRG hourly rainfall is disaggregated, and make sure the Poisson option is selected to use the Poisson disaggregator. Then click *OK*.

A progress bar will appear informing the user that the disaggregation calculation is proceeding. Once complete the user is returned to the Control Interface form. You have now disaggregated the data to five minute values.

You are now in a position to export the disaggregated data to either HydroWorks or RWIN format files.

Export

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To export data to a HydroWorks RED file click the *Create Output File* button on the Control Interface form.

You can save data to either a HydroWorks single events file or a HydroWorks multiple events file by selecting the appropriate boxes.

For this exercise, we require the top 50 storms sorted by mean hourly intensity. We have already sorted the storms. Therefore to select the top 50 storms sorted by mean hourly intensity enter 50 in the *Max No of Single Events to be exported* box.

Click *Browse* to select where the exported files will be saved and to name the files. Enter the name Storm in the file name box and click *Save*.

Click *Save* to save the files to the specified directory, next, click *Exit* to exit the File Export form and then click *STOP* on the main menu bar to exit STORMPAC.

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A.2 WORKED EXAMPLE 2

Task

Generate 10 years of data (20 years of daily data are available for a local site) and produce a chronological event file suitable for input to a SIMPOL model. Note: this worked example is intended to describe the use of STORMPAC and not necessarily producing a suitable input to a SIMPOL model.

Data inputs required

The data inputs required are as follows:

- 20 years daily rainfall data from a local site;
- Average SMD values for each month.

The source of these data can be found by looking at Section 5 of the main report.

Setup

Create a new database by clicking the *Create database* button on the Control Interface form. Save the database to a directory.

Import Daily Rainfall

After creating the database you must import your daily rainfall. Click the *Daily Data* button on the Control Interface form and open the relevant file. A progress bar then appears showing the progress of the data import. Once completed, a message box appears stating that the daily data has been imported successfully. Click *OK* and you are immediately taken to the Site Information form.

Site Information

Click the *Daily data* option in the Site Data Type frame. Fill in all the blank spaces in the Site Variables frame with the correct site information. In the Simulation Data Information frame enter 10 in the *Record Duration* box and 2000 in the *Starting Year* box. Click *OK* to calculate the site statistics and return to the Control Interface form.

SRG Data

To simulate rainfall you must first fit the NSRP model parameters to the sample statistics.

1. Click the *Simulate (SRG)* button to open the Parameter Fitting Interface form.
2. Select *Fit Parameters*.
3. Click the *Calculate SRG Parameters* button – a progress bar and counter will appear. The optimisation is achieved by the SIMPLEX method (see Press *et al*. [11]).
4. Click the *Simulate Rainfall* button to generate 10 years of rainfall. The rainfall is generated and then written to the SRGData table in your STORMPAC 4.1 database. The number of years generated was specified on the Site Information form.

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5. Click the *Select* button and choose a directory and filename for the CSV files.

6. Click the *Save Rainfall and Thresholds* button to create the CSV files.

7. A file of the generated hourly rainfall values is created. Each row in this file has the date and time and a value of hourly rainfall total (mm), the last line in the file has END written in it. Note: if opening this CSV file in MS Excel you may not be able to open the full CSV file because Excel files are limited to 65536 lines of data.

8. A CSV file with the suffix Threshold is created. This file contains frequency analysis results of the number of days when the daily totals, calculated from the hourly SRG data, are above a certain threshold. The thresholds are 10, 12, 14, 16 …..to……40 mm. A monthly summary of rainfall depths is also provided. If you have imported historical daily data the program will also calculate threshold frequency analysis results and monthly depths from the Daily table in the database. This is saved at the end of the Threshold file.

UCWI/API30

Follow the advice given in the UCWI and API30 section in Appendix A: Worked Example 1.

Events

You are now in a position to define some events from your simulated rainfall data. This is achieved by clicking on the *Event Definition* button on the Control Interface form.

1. For the purposes of this exercise put a value of 1 in the *Minimum inter-event period* box to identify all storms in your historical database.

2. Select the *Date* button in the Sort Criteria window to sort the database by date.

3. Select the *Ascending* option in the Sort Criteria window, which will sort the database in ascending order.

4. Select a directory and enter a file name by clicking the *Select* button. The generated events will be saved to this file.

5. Select the *Simulated* data type option at the top of the form. This ensures that the program will read data from the SRG data table in the database.

6. Click *Filter Events* and a progress bar and event counter will appear.

7. Click *OK* to the message box: “Events table successfully generated”.

8. The events as they are stored in the database will be displayed on the Control Interface form. Click on the *Close* button.

9. Click *Save Events* to save the events as a CSV file.

10. Click *Close* to return to the Control Interface form.

Disaggregation

To disaggregate the data you have to click the *Disaggregate* button on the Control Interface form. This displays the Hourly Rain Disaggregator form.

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Select the SRG option to make sure the SRG hourly rainfall is disaggregated, and make sure the Poisson option is selected to use the Poisson disaggregator. Then click *OK*.

A progress bar will appear informing the user that the disaggregation calculation is proceeding. Once complete the user is returned to the Control Interface form. You have now disaggregated the data to five minute values and are ready to export the disaggregated data to either HydroWorks, SIMPOL or RWIN format files.

Export

To export data to a SIMPOL file you need to display the File Export form by clicking the *Create Output File* button on the Control Interface form.

You can save data to a SIMPOL file format by selecting this option from the *Export File Type* drop down box.

For the purposes of this exercise you require all storms sorted in chronological order. You have already sorted the storms in the Event Definition form. To select all storms, leave the *Max No of Single Events to be exported* box blank. Select the *Simulated* option because the events were from simulated rainfall.

Click *Browse* to select where the exported files will be saved and to name the file. Enter a name in the file name box and click *Save*.

Click *Save* to save the files to the specified directory, when the message box “SIMPOL file export complete” appears click *OK* and *Exit* to exit the File Export form.

Click *STOP* on the main menu bar to exit STORMPAC.

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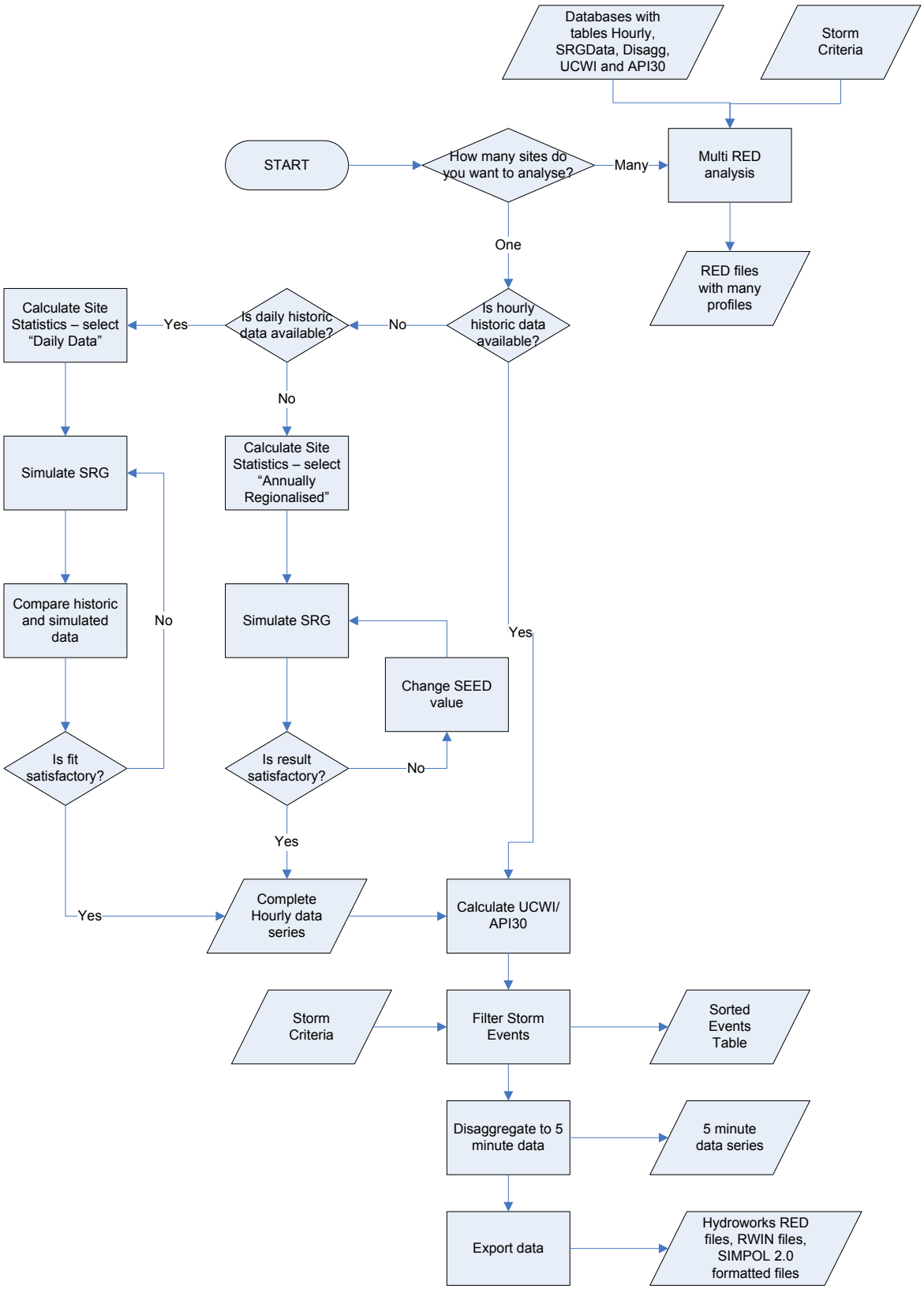
APPENDIX B FLOW DIAGRAM

Flow diagram showing a working methodology for using STORMPAC



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APPENDIX C REPORT FOR WRc ON A STOCHASTIC DISAGGREGATION PROCEDURE BASED ON A POISSON RECTANGULAR PULSES MODEL

Paul S.P. Cowpertwait, January 2005

SUMMARY

A Poisson rectangular pulses (PRP) model is fitted to wet sequences of 5-minute data extracted from a 31-year rainfall record taken from a gauge in Farnborough, UK. A comparison of simulated and historical quantiles verifies that the model is able to closely match the distributional properties of the 5-minute historical series. The historical series are aggregated to 1-hour time steps and disaggregated by selecting matching 1-hour aggregated totals of 5-minute series generated from the PRP model. The distribution of 5-minute rainfall given by the disaggregation procedure is compared to the historical distribution using high percentiles (extreme values) and quantile plots. The same procedure is used to compare the Ormsbee method of disaggregation currently implemented in STORMPAC. It is found that the new procedure significantly improves upon the Ormsbee method, especially in the tail of the distribution.

C1 INTRODUCTION

There are many stochastic models available for disaggregating rainfall. For example, there are those for downscaling output from global circulation models (e.g. Skaugen 2002; Venugopal et al. 1999) and those aimed at producing fine resolution data for urban catchment studies (e.g. Hingray et al. 2002; Cowpertwait 2001; Durrans et al. 1999; Koutsoyiannis 1994; Ormsbee 1989). In addition, there are models for disaggregating daily data to hourly data (e.g. Glasby et al. 1995; Koutsoyiannis and Onof 2001; Guntner et al. 2001) and models for infilling and disaggregating spatial data (e.g. Cowpertwait et al. 2004).

In this work we are interested in the disaggregation of hourly data to fine resolution data (5-minute time intervals) and seek to improve upon the method by Ormsbee (1989), which is currently implemented in STORMPAC. A number of approaches could be adopted. For example, a model based on random cascades, similar to that studied by Olsson (1998) and Guntner et al. (2001), could be fitted to hourly data and used to disaggregate to 5-minute series. Such models incorporate “scale invariance”, i.e. the statistical properties remain invariant at different time scales (subject to a scaling exponent). Clearly scale invariance can only apply to particular time scales, as, for example, annual time series (always recorded as non-zero in the UK) would exhibit very different statistical properties to daily series (which contain many zeros). Scale invariance is therefore at best a good approximation for some time scales. Although there is scope for further research into using such models for disaggregation of hourly data, in this work we adopt a model that has already been thoroughly researched. This is the Poisson rectangular pulses model, first studied in detail by Rodriguez-Iturbe et al (1987) and subsequently extended by Cowpertwait et al (2004) to disaggregated spatial hourly data.

The methodology we adopt is similar to that used by Glasby et al. (1995) in that ‘within storm’ rain cells have arrival times that occur in a Poisson process. However, these authors use a Bartlett-Lewis process to disaggregate daily data to hourly data, whilst our approach is to use a simple Poisson process to simulate fine resolution series directly.

C2 THE POISSON RECTANGULAR PULSES MODEL

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C2.1 Model definition and background

In the Poisson rectangular pulses (PRP) model, rain cells have arrival times that occur in a Poisson process with rate λ. Each rain cell has a random lifetime, which is distributed as an independent exponential random variable with parameter η. The intensity *X* of each rain cell remains constant throughout the cell lifetime; we will take *X* to be an independent Weibull random variable with parameters α and θ. The total rain intensity at any point in time is the sum of the intensities of all cells alive at that point.

Rodriguez-Iturbe et al (1987) compared the PRP model (based on an exponential distribution for cell intensity) to the Neyman-Scott and Bartlett-Lewis Poisson clusters models. The Poisson cluster models were shown to outperform the PRP model when fitted to full records of hourly data. However, as we shall be using the model for disaggregating wet sequences only, without attempting to fit long dry sequences between storms, this is not regarded as a reason to reject the model. Furthermore, Cowpertwait et al (2004) found that the spatial PRP model performed well when disaggregating hourly data for input in urban catchment models. Consequently, it seems reasonable to use the PRP for temporal disaggregation also, as this is just a special case of the spatial PRP model.

C2.2 Model properties and fitting procedure

Let Y_i be the rainfall depth in the *i*-th time interval (which for our purposes will be of duration 5 minutes). Then the following properties are given in the literature; the first two in Rodriguez-Iturbe et al (1987) and the last follows as a special case in Cowpertwait (1998).

The mean: $\mu = E(Y_i) = \lambda E(X) / \eta$ (1)

The autocovariance: $\gamma_k = \mathrm{Cov}(Y_i, Y_{i+k}) = 2 \lambda A_k E(X^2) / \eta^3$ (2)

The third moment: $\xi = E(Y_i^3) = 6 \lambda E(X^3)(\eta - 2 + \eta e^{-\eta h} + 2e^{-\eta h})/\eta^4$ (3)

In the above, $E(X^r) = \alpha^r \Gamma(1 + r / \theta)$, $A_0 = (\eta + e^{-\eta} - 1)$, and $A_k = ½ (1 - e^{-\eta})^2 e^{-\eta(k-1)}$ $(k>0)$.

The model can be fitted by matching the above properties to their equivalent values taken from the sample, which can be achieved using a minimisation procedure based on the squared differences; see Cowpertwait et al (1991, 2004).

C3 FITTED MODEL

C3.1 Parameter estimates

Using the above properties (μ, γ_0, γ_1, ξ), the parameters were estimated for each calendar month for a 31-year record of 5-minute data from Farnborough, UK. Following Cowpertwait et al (2004), only wet hourly sequences were included in the estimation of the sample properties. The parameter estimates are given in Table C1.

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Table C1 Parameter Estimates for Farnborough (1941-71)

Month / estimate	λ	η	θ	α
1	0.5771	0.4605	0.4890	0.0153
2	0.7480	0.4037	0.4409	0.0079
3	0.8003	0.6081	0.4663	0.0130
4	0.3899	0.6153	0.5878	0.0403
5	0.3480	0.7712	0.6006	0.0727
6	0.6499	0.7470	0.4357	0.0212
7	0.8737	0.8149	0.3351	0.0092
8	0.3078	0.6642	0.4947	0.0575
9	0.2686	0.6790	0.6282	0.0902
10	0.3088	0.7365	0.5831	0.0821
11	0.3649	0.5605	0.5657	0.0462
12	0.2863	0.4616	0.6445	0.0479

C3.2 Simulation tests

Using the fitted model, 50 years of 5-minute data were simulated for each month. The historical and simulated distributions of 5-minute rainfall were compared on quantile plots for each month separately – examples for January and July are given in Figures C1 and C2 respectively. In a quantile plot, points of equal probability of occurrence are plotted, providing a good way of comparing two distributions; the ideal is all points lying close to the line. Some discrepancies can be seen in our plots, e.g. the differences in the highest points. Some of these discrepancies could in fairness be attributed to sampling error, as the largest points have relatively high standard errors. Quantile plots are a rigorous visual comparison of two distributions, with a tendency to exemplify differences in the distribution tail (i.e. extreme values), so that overall the quantile plots add credence to the use of the fitted model in the disaggregation procedure.

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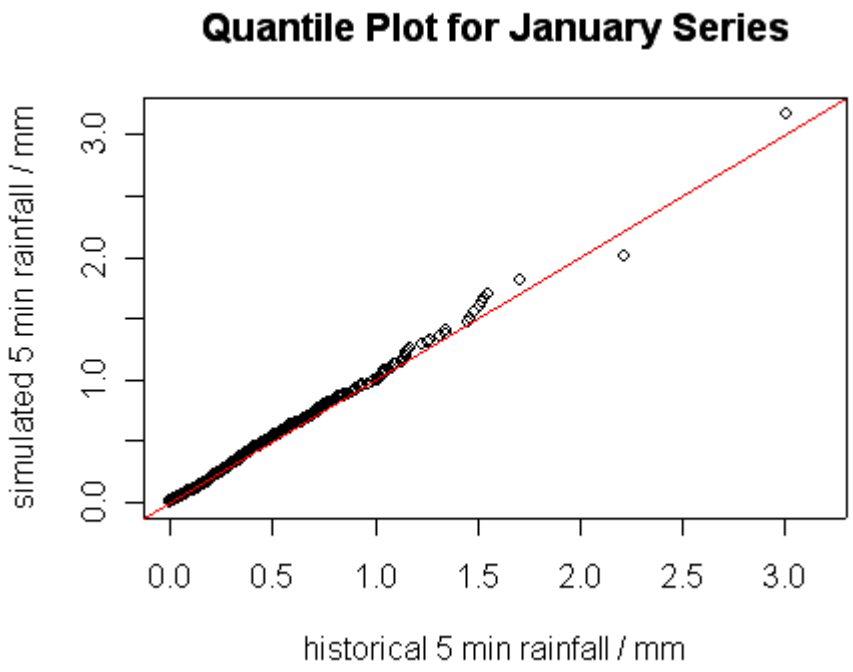

Figure C1 **Comparison of Historical and Simulated 5-Minute Rainfall Distributions for January**

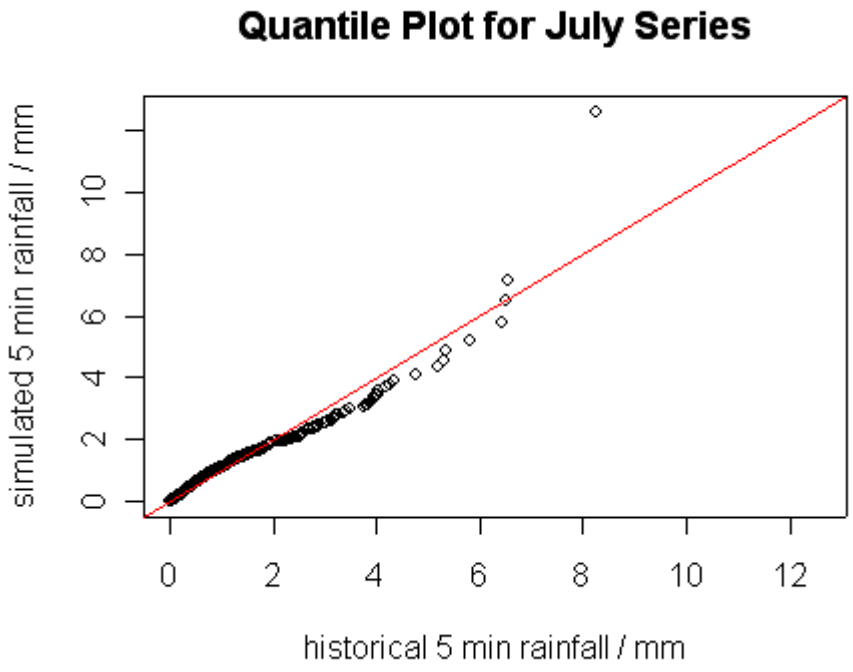

Figure C2 **Comparison of Historical and Simulated 5-minute Rainfall Distributions for July**

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C4 DISAGGREGATION PROCEDURE

C4.1 Summary of the Algorithm

The disaggregation procedure can be summarised as follows. A 1-hour rainfall depth is read in from a file, which contains the hourly series to be disaggregated. A 5-minute series is simulated using the fitted model. The 5-minute simulated series is summed and the 1-hour total of the simulated series compared to the 1-hour total that was read in. The simulated series is discarded if the absolute difference between the simulated 1-hour total and the total read in exceeds 0.05 mm. The process is repeated until the totals are in agreement to within 0.05 mm. The simulated series then represents a possible realisation of 5-minute data representative of the 1-hour value that was read in. Following this procedure, a record of 1-hour rainfall depths can be disaggregated.

In the above procedure, some additional rules are applied. These include using overlapping 5-minute values from the previous disaggregated hour provided the total of these overlapping values do not exceed the 1-hour total to be disaggregated. This allows for some influence, due to overlapping cells, from the previous hour. In addition, the disaggregated series are scaled to achieve an exact match to the hourly series (although clearly this is only a very minor adjustment, given they fall to within 0.05 mm of the hourly total).

It should be noted that the disaggregation procedure is not accounted for when fitting the model – it is a separate procedure that could be applied to any model capable of simulating 5-minute series. Therefore it is likely that some (probably small) bias would be introduced into the distributional properties of the resultant disaggregated series.

C4.2 Tests

The Farnborough data were aggregated to hourly values and then disaggregated using the above procedure. The distribution of the resultant disaggregated series was compared to the historical 5-minute distribution using quantile plots; the results are shown in Figures C3-5.

Figure C3 gives the overall result, where the data for all months have been pooled. From this figure it can be seen that the distribution of the disaggregated series compares favourably to the distribution of the historical 5-minute series. The exception is a slight curvature in the mid to lower part of the plot, which would translate into a slight over-estimation in part of the distribution tail. The plots for January and July show a similar pattern, i.e. a slight over-estimation for some of the distribution tail (Figures C4 and C5).

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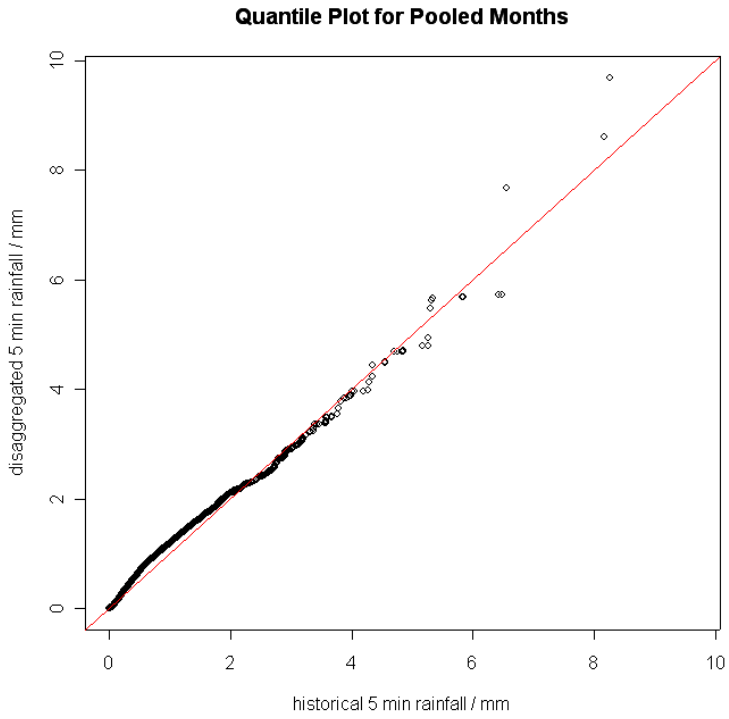

Figure C3 Comparison of Historical and PRP Disaggregated 5-Minute Rainfall Distributions for all Months in the Farnborough Data Set

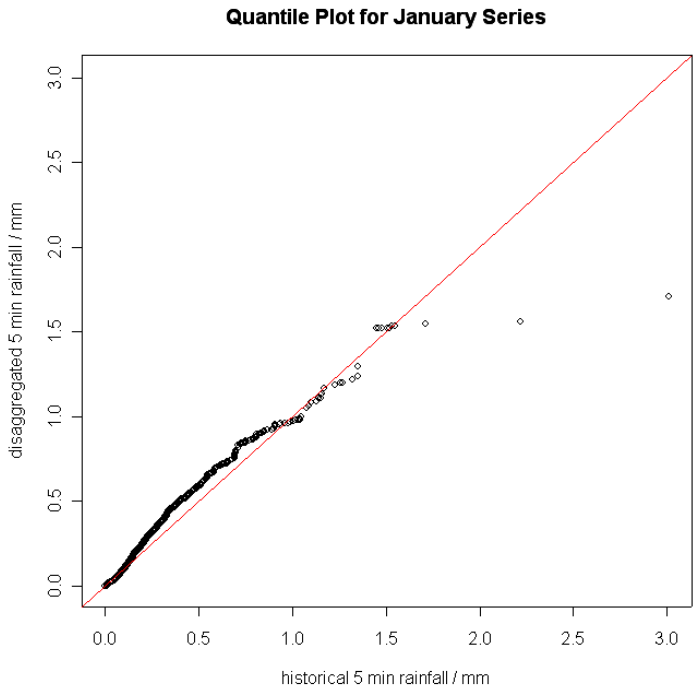

Figure C4 Comparison of Historical and PRP Disaggregated 5-Minute Rainfall Distributions for January Series in the Farnborough Data Set

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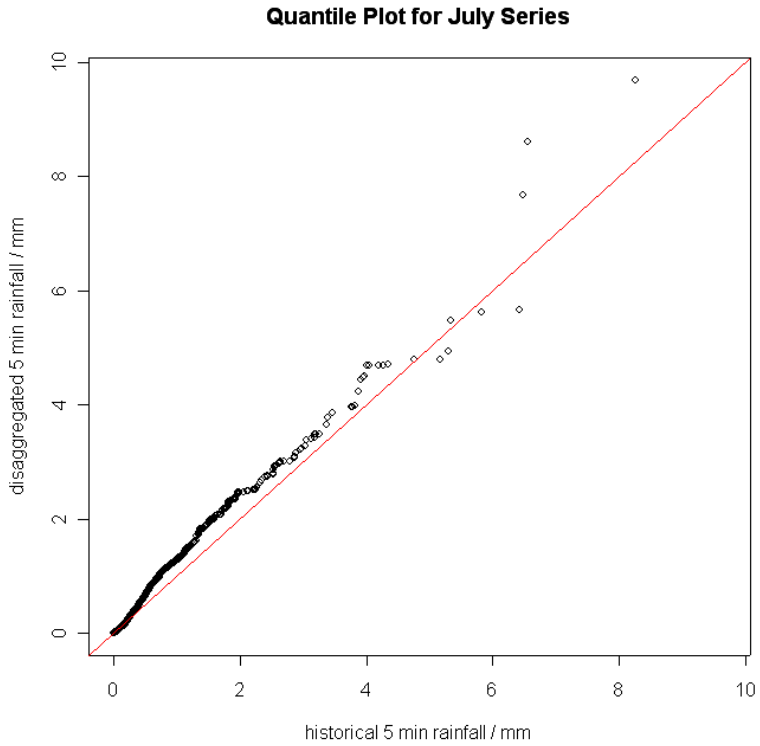

Figure C5 Comparison of Historical and PRP Disaggregated 5-minute Rainfall Distributions for July Series in the Farnborough Data Set

C5 COMPARISON WITH THE ORMSBEE DISAGGREGATION METHOD

C5.1 Quantile plots

The aggregated 1-hour Farnborough data were disaggregated using the Ormsbee method currently implemented in STORMPAC. The distribution of the resultant disaggregated series was compared to the historical 5-minute distribution using quantile plots (Figures C6-8).

Figure C6 gives the overall result, where the data for all months have been pooled. From this figure it can be seen that the Ormsbee method produces a consistent under-estimation in the distribution tail, i.e. the Ormsbee method fails to produce sufficient extreme values. The plots for January and July show a similar pattern, i.e. a consistent under-estimation of extreme values (Figures C7 and C8).

Comparing the plots (Figures C3-5) for the PRP method with the equivalent obtained from the Ormsbee method (Figures C6-8 respectively) it is clear that the PRP method improves upon the Ormsbee method. It should be noted that this is a fair comparison because the Ormsbee model was also calibrated to the Farnborough data set (Cowpertwait et al. 1991).

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C5.2 Extreme Values

A more detailed analysis of the extremes, which are likely to cause overflow problems, can be obtained by estimating the high quantiles of the distributions. These are shown in Table C2.

The PRP method represents the extreme values well; overall providing a better fit to the historical series than the Ormsbee method (Table C2). The exceptions are the 95-th and 99-th percentiles, which are over-estimated by the PRP method. However, the actual differences between the values are approximately 0.04 mm for the 95-th percentile and 0.17 mm for the 99-th percentile, which may not be of practical significance.

Table C2 Extreme values: Upper Tail Quantiles*

Quantile	Historical / mm	Ormsbee Method / mm	PRP Method /mm
0.90000	0.120	0.138	0.120
0.95000	0.200	0.223	0.243
0.99000	0.510	0.469	0.679
0.99900	1.550	1.002	1.697
0.99990	3.486	1.937	3.363
0.99999	6.266	3.292	5.713
1.00000	8.270	4.811	9.686

* All three distributions have exactly the same mean (0.0464 mm) to three significant figures, and have standard deviations of 0.129 (historical), 0.102 (Ormsbee method), and 0.149 (PRP method).

C6 CONCLUSIONS AND RECOMMENDATIONS

Some differences between the historical and PRP distributions were found around the middle part of the distribution tail. These differences were of small magnitude and may not be of practical significance. This could be verified through some flow simulation experiments, e.g. using a drainage model of a simple sewer network.

Overall, the PRP disaggregator showed a notable improvement upon the Ormsbee method, especially in regard to the extreme values. Therefore it is recommended as a suitable replacement to the Ormsbee disaggregator.

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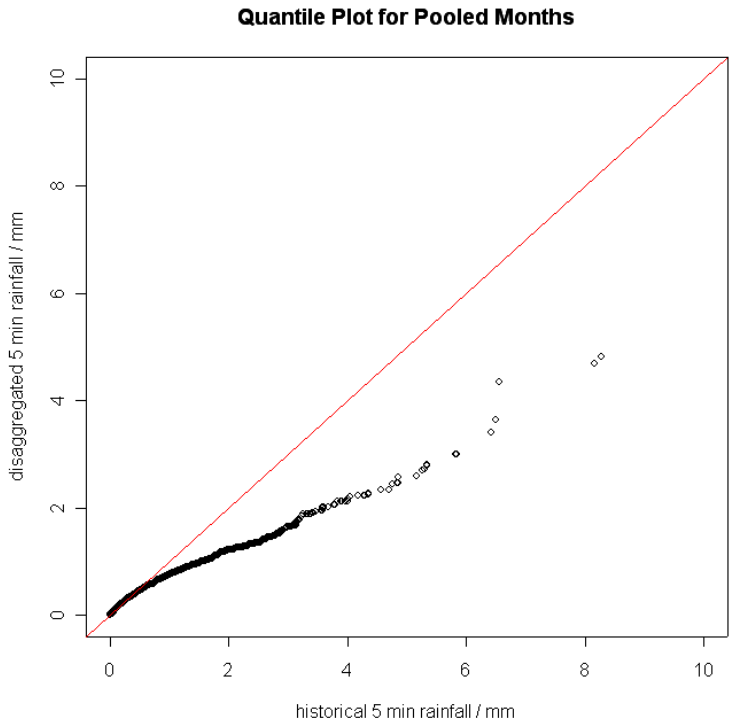

Figure C6 Comparison of Historical and Ormsbee Disaggregated 5-Minute Rainfall Distributions for all Months in the Farnborough Data Set

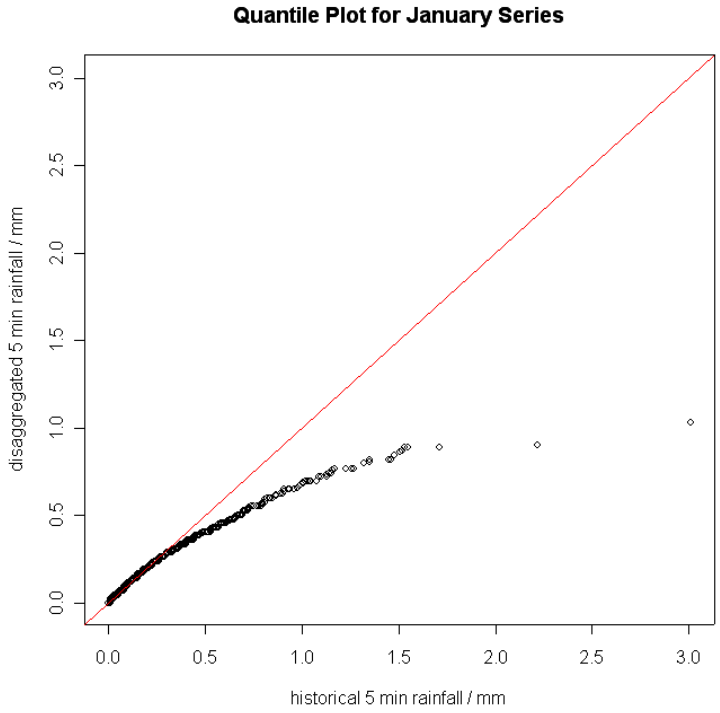

Figure C7 Comparison of Historical and Ormsbee Disaggregated 5-Minute Rainfall Distributions for January Series in the Farnborough Data Set

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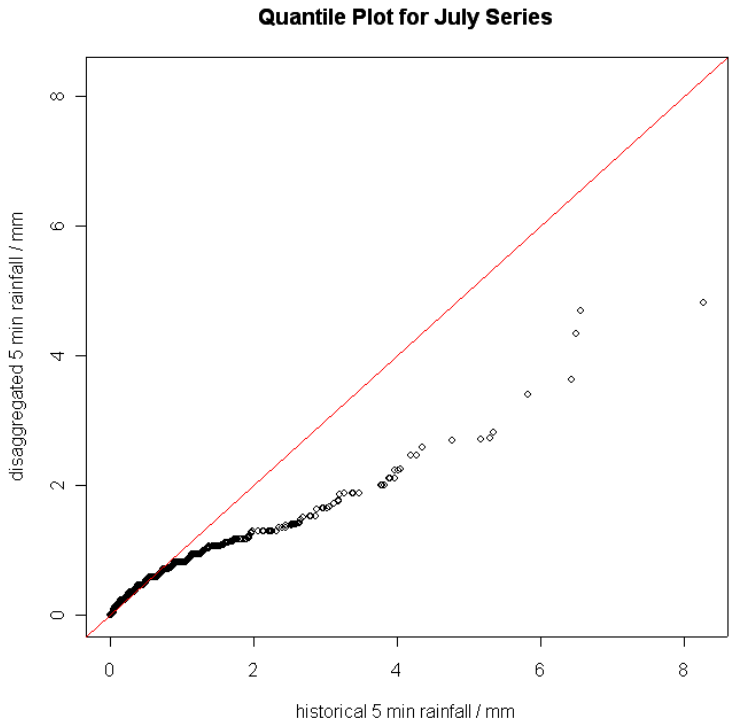

Figure C8 Comparison of Historical and Ormsbee Disaggregated 5-Minute Rainfall Distributions for January Series in the Farnborough Data Set

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APPENDIX D RED FILES FORMAT

IMPORTANT – RED files are right justified, and the spacing between numbers is vital. For example if a local UCWI value is 99 it would start 8 spaces from the left of the profile properties line. However, it is 250 then it would start 7 spaces from the left of the same line.

If there are missing spaces etc then this will cause errors when importing to InfoWorks. Therefore the format shown on next page must be maintained.

Location:

----1-ddmmyyyyhhmmss--sss----p----------GU--------GA---GE----W

--------LU--------LA--------LR---LE----W--EVENT 138 17:00 26/6/85 36

Sss = timestep in seconds
P = no of profile
GU = Global UCWI
GA = Global ANTEC
GE = Global Evaporation
W = Wetness Index
LU = Local UCWI
LA = Local ANTEC
LR = Local Areal Reduction factor
LE = Local Evaporation

NB. In InfoWorks:
If global value = 0 then local value is used
Event description is limited to 40 letters

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Location:

1 24062000160000 300 2 5 99.0 1.0 0

5 99.0 1.00 1.0 0NewUK_API 1

99 99.0 1.00 0.0 0Wallingford_UCWI 2

Location:

----1-ddmmyyyyhhmmss--sss----p----------GU--------GA---GE----W

--------LU--------LA--------LR---LE----W----------

5 Spaces to end of first integer
15 Spaces to end of date and time field
5 Spaces to end of timestep field
5 Spaces to end of number of profiles
20 spaces to end of global UCWI
10 Spaces to end of global ANTEC
5 Spaces to end of Global Evaporation
5 Spaces to end of Wetness Index number (not used)

10 spaces to Local UCWI
10 Spaces to Local ANTEC
10 Spaces to Local Areal Reduction factor
5 Spaces to Local Evaporation
5 Spaces to Wetness Index Model (not used)
Then from this point on is text

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